THE UNIVERSITY
OF ILLINOIS
LIBRARY

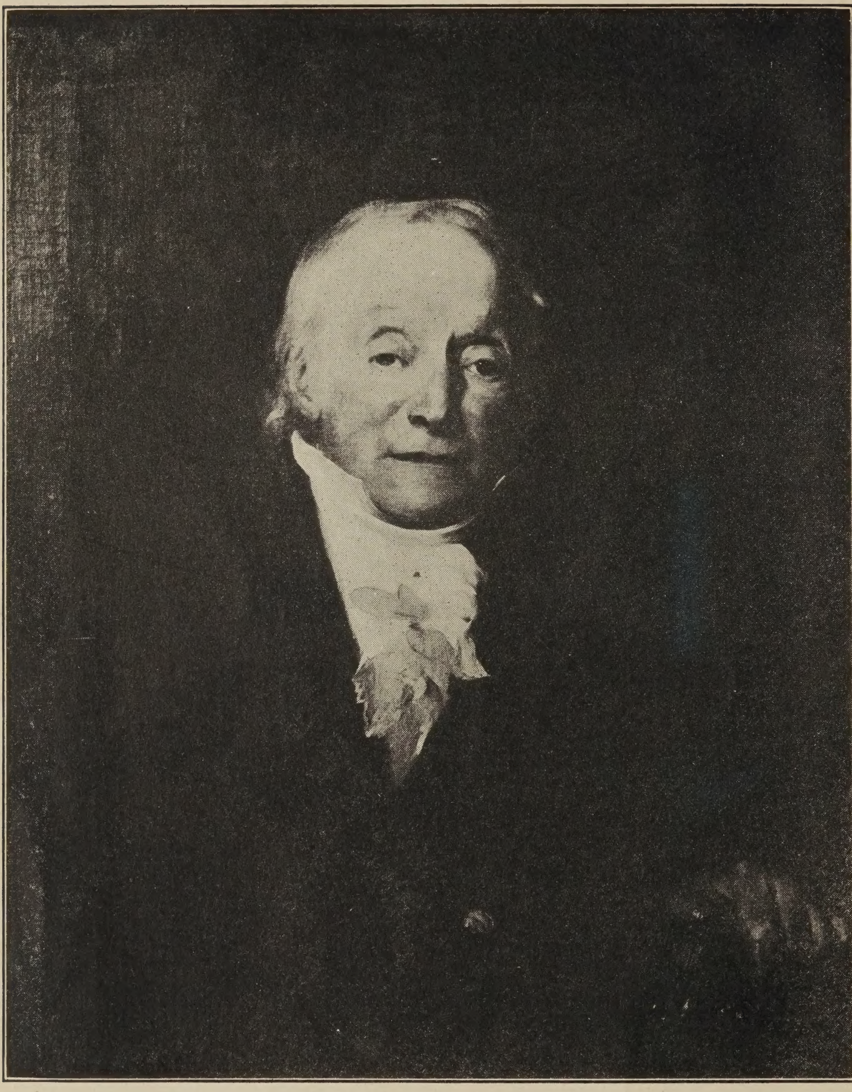
623.05
PR
v.11
Cop. 3

[redacted]

THE LIBRARY
OF THE
UNIVERSITY OF ILLINOIS

Digitized by the Internet Archive
in 2021 with funding from
University of Illinois Urbana-Champaign

https://archive.org/details/militaryengineer1119unse



PROFESSOR JARED MANSFIELD
1759-1830

623.05
PR
v.11
cop3
19475
LIBRARY
UNIVERSITY OF ILLINOIS

OUTLINE OF THE TERRITORIAL HISTORY OF GERMANY

By

Col. W. R. Livermore
(Retired)

The written history of Germany hardly reaches back for 2,000 years; but by comparing the traces of the early inhabitants and the languages of their successors, we may infer that more than 2,000 years before the Christian Era, Europe was already occupied by men of the three great races from whom the modern population has sprung. In the South and West, the Mediterranean races appear to have lived in the lands bordering on the Mediterranean Sea, on the North Sea, and on the Atlantic Ocean. In the Central zone were the Alpine races in the mountain regions and the valley of the Danube, and on the shores of the Black or Euxine Sea. In the North, were the Nordic races, on the great Northern Plain, and in the lands on the North and Baltic Seas, and about as far north as the 60th parallel of latitude. The Mediterraneans are long headed, little and dark; the Nordics, long headed, large and blonde. The Alpines are round headed, and in size and complexion, intermediate between the Mediterraneans and the Nordics.

Languages furnish a convenient basis for the classification of races and tribes with or without definite political organization. As far back as about 1500 B.C., most if not all of the Nordic and Alpine races in Europe probably spoke Aryan, or Indo-European, languages, showing that their ancestors had long been connected in government, in trade or in other close relations. From the languages and traditions of the later inhabitants, and from other indications, we may infer that the Aryan speaking races of Europe then reached from Normany to the Urals and beyond, that the languages spoken in northeastern France, and in northern Germany as far as the Elbe, and perhaps in Denmark, were Celtic; those in Germany, between the Elbe and the Vistula and along the south shores of Sweden, were Teutonic; those in the valley of

452531

the Danube, and, as far as the Aegean Sea, were Thracian, between the Danube and the Adriatic Sea, Illyrian; east of the Vistula along its lower course, Lithuanian; from its upper course as far, perhaps, as the Volga, Slavonic. All these languages belong to the Aryan family; and those whose sites were nearest were most alike.

In this period, the Teutons and Scythians were probably Nordic, the Celts, Italians, Illyrians, Greeks, Thracians, and Slavonians, were Alpine, with more or less admixture of Nordic blood. Some of the Mediterraneans, and perhaps some of the Alpines, on the shores and islands of the Aegean Sea were partially civilized, while in the cold and inhospitable regions to the north, the Nordics and some of the Alpines were still fighting for a scanty subsistence. It is natural for all things living to expand. The Northern races were strengthened by their hardy life; as soon as they learned from their neighbors to organize and equip their armies, they began to encroach upon them.

The Greeks and the Thracians were the first Aryan speaking races to benefit from the Aegean civilization; and while the Greeks occupied Greece, the Thracians, whom Herodotus called the greatest people on earth except the Indians, expanded to the east, south and west, pouring into Asia Minor, crowding the Greeks and Illyrians into Greece and Italy, and swarming over the Mediterranean Sea.

By 1000 B. C., the Thracians had perhaps entered Bohemia, and made inroads or settlements in northern Italy. The Celts and Teutons, on the shores of the North and Baltic Seas, had acquired some of the rudiments and tools of civilization coming up the Rhône, the Danube, and the Dniester; and down the Rhine, the Elbe, and the Vistula. The Celts had learned enough from their southern neighbors to become quite powerful. Their expansive impulse carried them south into Gaul, west into the British Islands, and north to the shores of Norway, while yielding slightly to the pressure of the Teutons on the Elbe, and then on the Weser. By 500 B. C., the Celts had all but the southeastern part of Gaul, and were crossing the Pyrenees into Spain where they mixed with the old Mediterraneans and formed the Celtiberians. The Teutons crowded them in the north, and mixed with them, perhaps as the military and ruling class, to form the Volcæ or Belgæ, who occupied the northeastern part of Gaul, and first the southern and

then the eastern part of Britain, where they formed the Brythonic, while the first wave mixed with the old inhabitants and were known as the Gaelic or Gadhaelic Celts. About 400 B. C., the Celts poured down the valleys of the Rhône to the South, and down the Danube, the Drave, and the Save to the east; they crossed the Alps into Cisalpine Gaul, and the Hyrcinian forest into Bohemia. Two or three generations later, Philip and Alexander the Great were glad to hold the Balkan peninsula against the avalanche. At about this time, Rhaetia, which had been held by a race more or less related to the Thracians and Illyrians on the east, and to the Etruscans on the south, fell into the hands of the Celts.

The first Celtic waves had been formed mainly of the original or Gallic branch; but all the Celtic and Teutonic mass was expanding, and from about 300 B. C., the Volcæ or Belgians, led the eastern hordes which then poured down the Danube to the Black or Euxine Sea where, about 270, they founded the great Celtic kingdom of Tylis reaching from the Tyras, the modern Dniester almost to Byzantium; they sent bands of warriors into the heart of Asia Minor where they finally established the kingdom of Galatia. Side by side with this movement down the Danube, a stream of Belgians and Teutons was probably moving east just north of the Carpathian mountains. After they settled down on the shores of the Euxine, the force of the current was spent. The Celts soon lost the lower Danube, but they settled in small bands in most of the region they had occupied. Until about the Christian Era, the Rhine, the Main, the Hyrcinian Forest, and the Carpathians, kept back the Teutons.

While these migrations were sweeping over Central Europe, powerful nations had grown up in the south. Under the influence of the old Aegeans, the Greeks developed a much higher civilization; but as their peninsula is cut up by mountain ranges and indentations of the sea, the states that they organized could not expand, but held each other in check, until Macedonia, which was less confined, outgrew and overpowered all the others. In Italy, civilization came later; but the land was united, and a great republic grew up, which by about 260 B. C., had spread over all the peninsula and by 100 B. C., over most of the European shores of the Mediterranean; it extended to the Rhine in the sixth, and to the Danube in the second decade before the Christian Era. Just

at the Era, the Romans reached the Elbe for an instant, and were then driven back to the Rhine, which with the Danube formed the boundary line of the Roman Empire for nearly four centuries; excepting that in the second century, the Romans crossed the lower Danube and established the new province of Dacia. In the first decade after the Era, the Teutoic Hermunduri, as the Romans called them, the Marcomanni, and Quadi, pressed south across the Main and the Hyrcinian Forest, and drove the Celtic Boii out of Bohemia and the land a little to the east and west. While the rest of the Empire was at peace, border warfare was kept up along the Rhine and the Danube, which exhausted the strength of the border tribes but taught them and their neighbors how to organize and fight. The small bands which were fighting each other formed little confederacies which fought each other as well as the Romans.

In the second century after the Era, from the same causes and influences which had enabled and prompted the Celts to extend their power from the shores of the North Sea to the Euxine and almost to the Pillars of Hercules, the Teutons, a Nordic race on the southeastern shore of the Baltic Sea began to expand, and started a series of migrations which were destined to extend their power over Western Europe, even farther than that of the Celts had been extended before. The Goths from the Vistula first moved to the west and south; but encountering the Romans on the Danube, they were driven back and followed the line of least resistance down the river to the Black Sea, conquered the province of Dacia and occupied the land for two hundred years. At about 350, the lower course of the Rhine was held by the Franci, or Franks, the upper by the Alamanni. The shores of the North and Baltic Seas by the Frisians, Varini and Goths. The Modern Holstein by the Saxons. North of them were the Angles who also mixed with the Varini to form the Thuringians in Central Germany. The middle course of the Elbe was held by the Langobards, the valley of the Main by the Burgundians, Bohemia by the Marcomanni; to the east were then the Quadi, the Gepidæ, Visigoths and Osthrogoths. The Vandals, neighbors of the Goths, were permitted by the Romans to settle south of the Danube. The great Leibnitz, statesman, scientist and philosopher, was perhaps the first to point out that these bands or kingdoms in western and central Germany were not the confederacies of small tribes that had been fighting

the Romans; but, that the latter formed only the lower and middle classes, while the ruling class came from the shores of the Baltic; and, by holding the old tribes in subjection, served to give strength and cohesion to the mass.

Along the Volga, the Goths were met by a great avalanche from beyond the Urals. At periods of about 300 years interval, the shepherds and herdsmen of northern Asia, learning enough from their southern neighbors to arm and organize their scattered bands, have rolled like snowballs, gathering in all the bands of the great plateau; and, then after gorging themselves with plunder, have lost their coherence, broken up into smaller hordes and then disappeared. The Huns were Asiatic savages of the Tartar-Mongolian type, their followers were composed of all the nomads that they could sweep along. At about 380 A. D. they met the Goths north of the Euxine Sea and drove them back. By A. D. 400, they had reached the lower Danube in the south and perhaps the Oder in the north, incorporating all they could hold, and driving the rest before them. The Goths took refuge behind the Danube, at first by the good will and then in despite of the Romans. By 410, the Teutons, fleeing before the Huns, were swept all over western Europe. All that could move were scampering to the south and west. The Romans were buried or scattered among the fragments. The Visigoths from the Danube overran Italy, the Suevi, Vandals and others took Spain. The Franks poured over the Rhine on its lower course, the Alamanni on its upper course. The old Celtic population in western Gaul and in northern Spain, then called the Bagaudæ, cut loose from the Romans. A few Angles from Jutland landed in England and the Saxons from the modern Holstein in France and Scotland. By 450, however, the Romans had recovered Italy and the greater portion of France; the Huns under Attila had reached the Rhine and absorbed all the population as far as the Elbe. The Romans and barbarians west of the Rhine united against him and at the first battle of Chalons in 452, his course was stopped. In 454, his Empire fell to pieces, but the Teutons still moved on.

In 460, when the curtain rises, we find the Visigoths from Italy in Southwestern France, the Burgundians from Central Germany between the Alps and the Rhône, where they had been planted by the Romans to stop the influx of more dangerous savages; the Alamanni and Franks are in their old seats, but much expanded.

The Bavarians from Thuringia are moving south through Bohemia, east of them are the Langobards, then along the upper middle course of the Danube, the Rugii, Scyri, Turcilingi, Heruli and Gepidæ from the Baltic; on the left bank, the Ostrogoths on the right. All of northeastern Germany from the Vistula to the Elbe, where the Goths once dwelt, is now occupied by the Slavonic tribes. There is little or no authentic account of this region for about three hundred years. According to ultra-Teutonic historians, after the Goths left this region in the second century after Christ, the land was vacant for years, perhaps for a century or more; but there are strong reasons to believe that the Slavs moved in as fast as the Goths moved out, and perhaps their resistance or pressure encouraged the Goths to move to the west and south. During the Hunnish occupation, Slavs in large numbers were probably drifted to the west, and when Attila's army was dissolved, many Slavs and probably a few Huns were left in the region south of the Baltic. The main body of this army fell back to the lowlands extending from the Danube to the Volga, where the Huns were afterwards known as Bulgarians.

In 476, the western Empire of the Romans was brought to an end by the revolt of the auxiliaries headed by the Heruli who placed their chief Odoacer on the throne as King of Italy. At Soissons, Syragrius, the governor, still held sway over a large district in northern Gaul, and styled himself King of the Romans.

The Franks, Alamanni, Burgundians and Visigoths now struggled for the mastery of Gaul. The Visigoths and Burgundians expanded until all southern Gaul was divided between them. The Franks were partially united in two confederacies, the Salians in Belgium, Artois, etc., the Ripuarians just above them on the Rhine and the Moselle. These confederacies were split up into small bands, each under its own chief or kinglet.

In 486, Clovis, a Salian chief, defeated Syragrius and put an end to the Western Empire and then extended his boundary to the Seine. In 496 he conquered the Alamanni, and took part of their territory. He and his pagan followers were then baptised as Roman Catholics. This gave him the support of old population. Of all the invaders, the Franks had been furthest removed from Roman civilization. According to Leibnitz' theory, the ancestors of their ruling class had come from the shores of the Baltic. They

are described as vigorous, cruel and barbarous. They knew little of cultivated life, and were glad to divide with the priesthood the control of the Roman populace.

The Burgundians and Visigoths were then more civilized, but they had adopted the Aryan form of Christianity. In 507, Clovis assembled his warriors and explained to them that it grieved him to see that the Aryans still possessed the fairest portion of Gaul. "Let us march against them with the aid of God," he said, "and having vanquished the heretics, we will possess and divide their fertile province." And they did. Clovis poisoned and otherwise disposed of the petty princes of his own people and laid the foundation of the kingdom of Merovingians, which, when, in 834, the Burgundians were conquered, included almost all of ancient Gaul. In 531, part of Thuringia was incorporated and the Alamanni were made dependent. Clovis died in 511, and the kingdom was then divided between his three sons. Early in the sixth century, the Saxons crossed the Elbe and occupied the valleys of the Weser and the Ems. About 560, the Avar horde, another wave of Asiatic savages, made its appearance in the east. In league with the Langobards, they destroyed the kingdom of the Gepidæ on the Danube, and then occupied the land of the Langobards, who crossed the mountains to Italy and gradually drove out the Romans of the Eastern Empire, who were holding it. The Avars subjugated the Slavs and held all of eastern Europe from the Volga to the Elbe, from the Baltic Sea to the Danube.

They planted the Slavs along all the border lands and drove them across into the Balkan peninsula to "blunt the swords of the Romans before they encounter those of the lordly Avars." In 626, the Avars met the Persians under the walls of Constantinople; but, soon after, their power was scattered and a number of independent Slavic states, Croatia, Serbia, etc., were established under protection of the Roman Empire of the East. For their own use and that of their animals, the remnant of the Avars occupied the lowlands along the middle course of the Danube and the valleys of the Theiss and Pruth as far as the Dniester, thus dividing the Slavs into two masses, the Poles, Tchecks, Slovaks, etc., on the north and the Carinthians, Crovats, Serbians, etc., the Jugo or South Slavs on the south.

At the same time, Samo set up the first great Slavonic kingdom, which, starting from Bohemia, extended south to the Styrian

Alps, east to the Carpathians, north to the Spree, and the Havel, and west as far as the Main. From the latter part of the seventh until the early part of the ninth centuries, the Frankish writers appear to make no mention of this first Czecho-Slovak kingdom, but it is certain that during this period the Slavs were independent and probably prosperous.

For more than two centuries, under Clovis' descendents, the Merovingians, France was again and again broken up and reunited. According to Teutonic law, the land was divided among the heirs; but they always quarreled until, by poison, sword, dagger, or otherwise, one made away with all the others. These changes therefore had little or no permanent effect upon the German boundary. In 679, Alamannia, which had been partially dependent upon Merovingian kings, became wholly detached; after about 640, Thuringia appears to have been practically free. Meanwhile the Saracens from Arabia had spread their sway over western Asia and northern Africa. In 711, they crossed the Straits of Gibraltar. In 732, having driven the Visigoths back into the mountains, they crossed the Pyrenees and invaded France, where they were defeated and driven back to Spain by Charles Martel, the Mayor of the Palace of one of the Merovingian kings, who in 752 were displaced by Pepin, the son of Charles who founded the dynasty of the Carolingians, under whom France took a new start. Thuringia and Alamannia were soon returned to the dominion of the Franks. In 754, the Frisians were reduced to subjection. In Italy, the Langobards or Lombards had conquered from the Eastern Roman Empire almost all the peninsula excepting Rome and its environs. The Pope appealed to the Franks for assistance. Pepin, their king, defeated the Lombards and transferred to the Pope the temporal power over the lands so long after known as the States of the Church. This gave to the new dynasty the ardent support of the Catholics in France.

In 771, Pepin died and was succeeded by his son Karl, afterwards known as Charlemagne, who, to secure his boundaries and extend Christianity, made war upon the Saxon confederacy in the valleys of the Ems and the Weser. In 774, called by the Pope to assist him against the Lombards, Charlemagne crossed the Alps and united to his kingdom all Italy north of the states already ceded to the Pope. In 778, having been asked to intervene in Spanish affairs, he extended his southern boundary to the Ebro.

In 780, after a series of long and bloody wars, he reduced and baptized the Saxons, and extended the boundary of his kingdom in the northeast as far as the Elbe. In the southeast, on the middle course of the Danube, a small remnant of the Avars still remained. In 784, the Slavonic Carinthians, for their own protection against these savages, made themselves tributary to the Bavarians. In 788, Bavaria, which for some time had been nominally tributary to the Franks, was finally incorporated, and Carinthia went with it. In 797, Charlemagne destroyed the Avars, and the power of the Franks extended to both banks of the upper and middle Danube. Before he died it had reached the Oder.

In 880, Charlemagne went to Rome and was invested by the Pope with the crown of the Roman Empire. At this time the Roman and Greek Catholic churches were finally separated. This freed the Pope from any allegiance to the Byzantine Empire, and gave Charlemagne the confidence and support of the people who had heard of the strength and glory of the old Roman Empire and felt that the days of peace and plenty had returned.

Charlemagne's reign marks a great era in the history of Europe. The wave of Teutonic migration is stopped. Of those who had lived in Germany in the second century, the Marcomanni and Quadi, who were the first to move out, have been absorbed by those who followed. The Goths and Vandals from the Baltic, who came next, have been so scattered over all the Mediterranean region that no trace of them is left except in a narrow strip along the southern coast of the Bay of Biscay. Saxons from modern Holstein and Angles from Jutland have colonized England. The other tribes and nations are incorporated in Charlemagne's empire. Of those in Germany in 350, the Alamanni, Franks and Burgundians are in France; the Angli and Varini are in Thuringia, except those who reinforced the Franks and Alamanni or who, as Baioarii, have occupied Bavaria. The Frisians are on the coast of the modern Holland. Saxons have moved from Holstein to the valleys of the Ems and Weser. The Lombards are in Italy.

Under the pressure from the Saracens in the southwest, and the Saxons in the northeast, the Franks had united their forces and subdued the Avars in the East and incorporated the Lombards in the south. By the genius of the greatest man of his age, men of the three great races were consolidated into a great organism, to which the Nordics gave strength and individuality, the Alpines

organization, and the Mediterraneans refinement. Many generations were required for these forces so to react that the permanent government could be established which was to pave the way for the civilization of Modern Europe. Charlemagne established schools and encouraged the study of science, politics and literature. He so reorganized his empire as to take from the dukes a large part of their power, but he also deprived the Teutonic freemen of much of their individual power, and laid the foundations of the feudal system which prevailed in Europe throughout the middle ages.

1. Map of Europe in 1815 showing in color a tentative location of Celts and Teutons in the early ages.

Anthropological boundaries.	+ + + + + + +
Political boundaries, 1500 B. C.	
Political boundaries, 1000 B. C.	
Political boundaries, 500 B. C.	
Political boundaries, 340 B. C.	
Political boundaries, 250 B. C.	

THE LIBRARY
OF THE
UNIVERSITY OF ILLINOIS

2. Map of Europe in 1815 showing in color the approximate location of Teutonic nations, tribes, etc., about A. D. 350.

THE LIBRARY
OF THE
UNIVERSITY OF ILLINOIS

3. Approximate location of Teutonic nations, tribes, etc., about A. D. 410.

THE LIBRARY
OF THE
UNIVERSITY OF ILLINOIS

4. Approximate location of Teutonic nations, tribes, etc., about A. D. 460.

5. Approximate location of Teutonic nations, tribes, etc., about A. D. 480.

THE LIBRARY
OF THE
UNIVERSITY OF ILLINOIS

6. Central Europe about A. D. 520.

THE LIBRARY
OF THE
UNIVERSITY OF ILLINOIS

7. Central Europe about A. D. 620.

THE LIBRARY
OF THE
UNIVERSITY OF ILLINOIS

8. Central Europe about A. D. 770.

THE LIBRARY
OF THE
UNIVERSITY OF ILLINOIS

9. Central Europe about A. D. 830.

THE LIBRARY
OF THE
UNIVERSITY OF ILLINOIS

OLD AND NEW OPINIONS ABOUT THE VALUE OF PERMANENT AND FORTIFIED POSITIONS.[1]

(*Continued from No. 54.*)

X.

In the course of the year the various views and opinions concerning fortresses, fortified places, field defences, etc., have been presented and discussed. There have also been cited authorities, their treatment of the subject, the controversies that have arisen, while the historical development of land defence systems, more especially of ours (Switzerland), has been traced and described; while through it all the battle, old almost as war itself, between armor and missile, between gun and cover, its arguments, its lights and shadows, its ups and downs, has been maintained; and now it is in order to show how all of these fortress and defence systems, these theories and abstractions have materialized and received their practical demonstration in actual warfare.

It is true that the part played as a factor in the present war by the various kinds of fortifications has been touched upon in the present essay in a number of instances, and to a greater or less degree. But a compendious exhibit, with technical data and details, which might serve as an adequate illustration of the subject, has not as yet been made. We here present such a showing, for which we are indebted to American sources, based upon an article on artillery intelligence published in the *Journal of U. S. Artillery.*

Two prefatory remarks are here in place:

The extracts do not, as a matter of fact, contain anything novel; they fail in some instances to go as fully as they might into details, while in others they are not always accurate as to the true facts in the case; but they present the views held by the General Staff of the United States Army as to the how and why of the

[1]From *Schweizerische Zeitschrift für Artillerie und Genie,* December, 1917. Translated from the German by Maj. Henry Swift, Chaplain, U. S. Army, Ret.

conquests of the Belgian, French, and Russian forts, as well as their opinions as to the value of the fortresses, as far as their construction was then up to date, and their future modifications; opinions which are authoritative: for the passages quoted from the *Journal of the U. S. Artillery* constitute a portion of the archives of one of the War Colleges of the General Staff, and are official memoranda on the lessons to be learned from the European War.

The passages cited give, first of all, some details concerning the several fortifications, their structure, equipment and garrisons, and then briefly recount the character of siege or bombardment. In conclusion are given practical and compendious comments. In general we follow this order, supplementing, however, and rectifying as far as possible in the light of more recent sources of information. The conclusions, however, are adhered to entirely according to the tenor of the extracts from the *Artillery Journal.*

LIEGE.

The fortifications, built according to Brialmont's plans, were finished in 1892. They consisted in their main features of a circle or ring of forts, commanding the approaches to Liege, ranging at about 6.5 kilometers from the city. They comprised six principal forts of the old pentagonal type, and six three-cornered forts of lesser size. The greatest interval between any of these forts was 6,400 meters, while the average distance was less than 3,700 meters. Each fort had a garrison of eighty men, and an armament consisting of two 15-cm. and four 12-cm. guns, two 20-cm. mortars, and three or four rapid-fire guns, which latter were mostly shielded by armor-plate. The total of pieces for the twelve forts was four hundred. The intention had been to establish field-works between, but this was never carried out.

When the German invading forces fell suddenly upon the Belgians who had so far mobilized, the latter, instead of the 30,000 they had expected to muster, were only able to man their works with 20,000 men. This unlooked-for attack was directed against the four forts of the southern section.

Fire was opened by the German artillery on the night of the fourth, and continued through the fifth of August, field-pieces being employed, whereby on the fifth of August one of the forts was silenced. On the following day the Germans brought into action some 21-cm. mortars, and it would seem some of 28-cm.

caliber, as well as some 42-cm. cannon. The range of these pieces exceeded that of the Belgian artillery. Their shells penetrated through concrete facings 3.7 meters in thickness. When it became clear that the forts could no longer withstand the accurate fire of the Germans, on the afternoon of the 6th of August the Belgian forces were withdrawn from the city, and all the forts, with the exception of those on the north, were abandoned. These last the Germans began to bombard on August the 13th, using 28 cm. mortars, as well as 42-cm. howitzers, and by the 15th of August they were all captured. The guntowers were shattered, the shells penetrated the domes, and the magazines exploded.

NAMUR.

The chain of defences here consisted of nine forts, which were about 4,000 meters distant from the city, and their armament was of the same description as that of Liége. The larger forts were each defended by two 15-cm. and four 12-cm. guns, and by two 21-cm. mortars armored, while the smaller forts were only armed with two 12-cm. guns and one 21-cm. mortar. As the 25,000 men composing the garrison could command more time for preparation than that of Liége, they were able to intrench the ground between, and to throw up breastworks covering the approaches. The Germans brought into action against these works, beside their small caliber guns, 42-cm. howitzers and 30.5-cm. mortars, and in addition to these some Austrian motor batteries.

On the 21st of August the infantry of the attack established themselves before the advance lines, and drove back the garrison by a simultaneous destruction of the villages which served as points of support. On the 22nd the fire of the Belgians abated considerably, and the effects of the heavy ordnance of the Germans was noticeably felt. On the 23d the German infantry were able to push forward under cover; the lighter pieces were advanced and opened fire on the works between along the line of attack. As a consequence the defenders were obliged to abandon these, and their assailants to push forward still further. On the 24th the fire attained its maximum intensity. On the 25th the infantry forced their way between the forts, driving their adversaries clear back to the city. Five forts surrendered, and while the city was still held, the other four forts fell, being bombarded from the rear.

The German fire had become extraordinarily severe. One fort had fired only ten shells, while it had been struck 1,200 times; which was figured to amount to twenty shots a minute. The firing was so continuous that no holding of the intervening works was possible. Fort Suarle, which was northwest of Namur, was bombarded from Sunday, the 23d of August, and fell—it being the first to yield—at five o'clock on the evening of the 25th. On the 23d it had been struck some 800 times, on the 24th about 1,300 times, and by about 1,400 shots on the 25th, these being fired by three batteries of very heavy guns.

The decisive points on the attack on Namur were as follows: Putting out of commission the inferior artillery of the defence. The destruction of the armament of the forts, a mark easily reached by the strong, superior artillery of the offensive, this being of the heaviest caliber. Pushing forward of the infantry under a covering fire of the artillery, which quickly commanded the situation. Breaking through the intervening lines, after having annihilated the fighting strength of the forts, the taking of which by storm had become entirely unnecessary.

THE FRENCH FORTRESSES ON THE NORTHERN FRONTIER.

Lille, Laon, La Fére, and Rheims, which had only been modernized to a limited extent, fell easily into the hands of the German advance, without any serious opposition being offered. The maintenance of these fortresses would have imperiled the safety of their garrisons, since the advance of the Germans was over such an extensive front.

The fortress of Maubeuge, which had been reconstructed on the lines of more recent improvements, had alone attempted to put up a defence. There the ground lying between the outer ring of forts, which were from five to six kilometers distant from the city, had already been carefully prepared in time of peace according to modern developments in the engineering art. The several broad stretches between were occupied by intermediate works of the latest style of construction, and the forts, which had been erected during the seventies of the last century, had been strengthened with concrete, armor, and casemated batteries under the flanks. In addition infantry intrenchments had been carefully thrown up over the intervening spaces, deeply sunken batteries emplaced and securely sheltered, barbed wire entanglements laid, and on the exposed

northeastern front was provided an armored battery train running on a belt line.

The fortress was invested by the German infantry on August the 28th. On the 1st of September the garrison made a sortie, which was effectually repulsed. The siege artillery, consisting of 26-cm. mortars, 42-cm. howitzers, and Austrian 30.5-cm. motor-mortars, was first placed in position on the 3d of September. The very first fire of these, at a distance of from eight to ten kilometers, demolished the forts and the works that lay between; so that the infantry were able to take positions for the assault, and break through the intervals. On September the 8th the fortress with its garrison of 40,000 men surrendered, after the advancing fire of the German artillery had succeeded in reaching the old Vauban walls of the city, and the town itself.

The course of the siege furnishes these points as determinative of the result. The investment, bringing the batteries into position; the attack on the forts, bringing up the infantry under the protecting curtain of artillery fire; the attack on the works lying between the forts and the break-through of the infantry; only, thanks to the extensive range, the accuracy of fire, and the ponderous blows of the German-Austrian guns in the advance against what artillery the defense could bring against them, inferior as they were in weight and range, no available resistance was possible; and, thanks also to their extraordinary facility in delivery of fire, the different stages of the siege followed very quickly one on the other.

ANTWERP.

Before the war Antwerp was reckoned to be the second strongest fortified place in Europe, and was held up as a prototype of the Brialmont art of fortification. The works were so laid out as to take every advantage of the water-courses and swamp-land, and the city was girdled by two rings of forts, of which the inner circle replaced the more ancient walls of the city. It lay 4 kilometers distant from the city proper, had a circumference of 45 kilometers, and consisted of 14 forts of modern type. The outer girdle of forts was about 15 kilometers distant from the city, and 19 forts were embraced in the entire belt, extending about 100 kilometers. Between the several forts were permanently erected works, equipped with artillery. The forts and batteries adjoining the Scheldt and the canals could be

rendered entirely immune from assault by flooding the circumjacent region. It was generally believed that this inundation by the Antwerp defence would play an important part. The artillery equipment was similar to that of Liége and Namur, none of the guns exceeding 15 cm. in caliber, nor any mortars being of greater caliber than 20 cm. Most of the guns were protected by armor-shields.

The German siege-artillery consisted, as in the other cases, of 21-cm. mortars, 42-cm. howitzers, and 30.5-cm. mortars of the Austrian motor-batteries, disposable at any point. The attack was principally directed against the section which lay between the Dyle and the railroads leading from Antwerp eastward. In this sector lay along the Nethe Forts Lierre, Koninghoyck, Wavre St. Catherine and Waelhem, and the intervening works, denominated respectively Tallaert, Boschbeck, Dorpfeld, and the railroad redoubt Duffel. They constituted the sixth engineer district of Antwerp, and had a frontage of from 15 to 20 kilometers. The garrison, taught by the experiences of Liége and Namur, tried to prevent the enemy from getting their heavy howitzers within range of the forts, but they were driven back by the overwhelming superiority of the German besieging forces, so that the latter were able to bring up their siege guns and in brief order destroy the forts. The ''impregnable'' fortifications were able to hold out for only twelve days. On the 28th of September the first shot was fired by the besiegers. On the 1st of October they were masters of the first forts. On the 6th and 7th of October the infantry, despite a most obstinate resistance, won a strong footing on the Nethe sector. At midnight of the 7th and during the morning of the 8th they opened and kept up fire on the inner line of fortifications, as well as on the city itself. On the 8th of October two of the forts on this line were taken, and on the 9th the city, abandoned by its garrison, was captured, the opposition offered scarcely deserving the name.

The German military author Trebonius, writing for the *Technical War Journal*, says: ''As we consider the results accomplished in such an amazingly short time, where was overpowered a gigantic fortified system, equipped with every active and passive appliance for defence of the most approved modern type, we feel, judging from the conduct of a superior garrison, that they failed to exhibit in the most flagrant degree a spirit of offensive. In a strategical, as also in a tactical sense, they displayed this in ne-

glecting to assail the German lines of communication, in not availing themselves during the attack on the forts of every advantage which their preponderating strength and the make-up of a modern fortress provided, especially of one so well equipped as Antwerp. It looked as if the Commandant failed entirely to understand the fundamental principles of modern fortification, confining himself entirely to a passive defence, making no effort to utilize his superior forces in an offensive. Consequently the fate of this fortified place was practically decided when the assailant, having overcome the passive obstacles, had nothing more to do than reduce to silence their gun and rifle fire.

"The assailant possessed the necessary means, and they were employed masterfully. If the defence was characterized by a purely defensive attitude, on the other hand the attack was distinguished by an offensive spirit, infiltrated with a sublime courage, which was to be held back by no difficulties whatever. First and foremost the artillery, with their splendid weapons, and with an accuracy of aim that was astonishing, smashed the defences like so many earthen pots. But how was it that they could do this? Because these strong forts, to the Brailmont mind vast reservoirs of power, represented but a small, restricted area of action, as covered by them; because no shells fired at them went uselessly amiss, while in spread they found an easy mark in the wide-extended construction; because finally they were not provided with an armament whose fire could disturb the enemy's guns—there were no long wide-ranging pieces, only those with steep trajectories, supposed to possess such fabulous efficiency—the latter being so remote that the Belgian shots failed to reach them. Their guns were insufficient, inferior in construction, in no way attaining the characteristic of fortress guns—then hardly to be foreseen—of the later high trajectory type."

VERDUN, TOUL, BELFORT.

All of these, covered by girdles of forts thrown out far in advance, and by means of field-works constituting a strong defensive zone, are an essentially different proposition from the Belgian fortresses.

As at the first onset of the German Crown-prince at Longwy the Garrison of Verdun sought to meet him, so have both the forts of the barrier chain of defences, which serve as supports for the

flanks, up to the present persistently endeavored by sallies against the German positions, both on the plains of Woevre, as on the Meuse, and in the Argonne, to break through their lines; and they have thereby made so thorough an impression, that on the adversary's side, only at the first, and even then only by the most desperate efforts, have they been able to win any footing whatever. And likewise the garrison of Belfort has known how to utilize in the most skillful manner commanding positions at the foot of the Vosges, in order to make repeated forays into upper Alsace, from the heights to assail the German positions beneath, and to hold back the forces of the latter from the fortress itself.

Verdun, during the battle of the Marne, served as an impregnable point of support for the right wing of the French army, and thereby was a material factor in the success which crowned the battles there fought under French leadership. In the year 1916 its spirited defence not only furnished a most stubborn opposition against the attack of the army of the Crown-prince, but also contributed toward the dislodging of the Germans, who in their advance had succeeded in penetrating the outer chain of forts, and not only this but in driving them back to the positions from which they had emerged.

There were, moreover, still other weighty conditions that contributed to the successful maintenance of the three fortresses in question by the garrisons as offensive factors. The Belgian and northern French fortresses were entirely isolated, dependent upon their own strength and effective forces. On the other hand Verdun and Toul, as well as Belfort with Epinal, along with a chain of barrier forts thrown in between, constituted an organic whole, while the extremities of the wings were particularly strengthened on account of the favorable conformation of the country, whose points of support were mutually subsidiary for defence. And—what was of supreme moment—the fighting strength was, and is, dependent, not only on the garrisons of these forts and fortified places, but also on the army in the field, on which they can draw at will, and in any manner desired. It is true that the Verdun-Toul position was broken into by the capture of Fort Camp des Romains on the Meuse, but this rupture was compensated for by the fact that its loss did not effect the isolation either of Verdun or of Toul; for Verdun-Toul was still maintained as the supporting point for the right wing of the whole French army. The connecting link is the

Argonne, whose determined defence, as well as the crowding back of the German forces into the confined space between the Aire and the Cotes de Meuse, as also in Aisnetal on St. Menehould served to bottle them up effectually. A break-through in this or that direction would destroy the connection of the Verdun-Toul position with the army, and in consequence of such isolation the siege of Verdun, and later on an attack on Toul, would be made possible. This possibility was experienced and averted by the obstinate defence of Verdun in the years 1916-1917. It was in this instance that the mutual coöperation of army and fortress in most striking manner turned the scales.

PRZEMYSL, AND THE RUSSIAN FORTRESSES.

The Austrian fortress Przemysl had, like Antwerp, an inner and outer line of defences. The inner line consisted of a series of forts, which were connected with each other by slight earthworks, the forts themselves being strongly constructed. The total extent of the works was about 12 kilometers, there being six forts on each side of the San. The outer line, which covered a stretch of over 40 kilometers, consisted of independent forts with intervening works and batteries, on a circumference having a radius of about 6 kilometers from the city. On the left side of the San were twelve or thirteen forts with works between, and on the right side were seven independent forts, to which were added substantial fortifications in the intervals. The distance between the several elements of the works was not more than one kilometer.

This place was invested by the Russians for the first time on the 20th of September, 1914; but a little later on they raised the siege. On the 12th of November of the same year the siege was renewed; but as the besiegers possessed no artillery that was up to requirements, they contented themselves with trying to starve out the garrison, which was accomplished by the 22d of March. The Central Powers took just two days to recapture the place in May of 1915. According to the statement of the Russians they were deficient in ordnance, but it is safer to presume that the heavy German and Austrian siege guns had the greater part to play in the recovery of this stronghold.

Of the fortified places on the western Russian front the triangular group of Warsaw-Novogeorgievsk-Sierock is most particularly to be considered. This group, besides its defensive character, was

essentially available for an offensive, and in the latter played an important rôle when the first German-Austrian advance invaded Poland, being directed toward the Vistula and against Warsaw. At that time Warsaw and Novogeorgievsk served as bridge-heads to thwart all attempts on the part of the enemy to interfere with the bringing up of the mighty contingent of Russian reinforcements, a force which first brought to a halt, then shattered, and finally compelled the German-Austrian advance to fall back. They were also instrumental in covering the undisturbed passage of the bulk of the Russian army over the Vistula, and in masking their relatively unexpected appearance on the left flank of the Germans.

The members of this Polish three-cornered fortress system are situated either on great streams or at their confluence, Warsaw—with Praga—on the two sides of the Vistula (Warsaw on the right, Praga on the left), Novogeorievsk on the right bank of the Vistula at the mouth of the Nareff (Narew), Sierock at the junction of the Bug and the Nareff. So both of the last named fortresses covered and made possible the prevention of a hostile and disastrous passage over two broad water-courses. The distance between Warsaw and Novogeorgievsk is some 30 kilometers, between Novogeorievsk and Sierock likewise 30 kilometers, and the same again between Sierock and Warsaw.

So these three fortresses embrace an area with a circuit of some 150 kilometers, and constituted in their totality a gigantic fortified area, which in two directions, on the one side against Germany, on the other against Austro-Hungary, is defended by two broad streams, practically immense moats.

Their garrisons amounted to about 100,000 men, their armament to 2,500 pieces, concerning whose modernity, all things considered, there might be a certain degree of doubt; a doubt that might well extend to the construction of the fortifications.

Any one of these fortified places covered and protected the others, but least of all, however, on the stream or waterside. If the attempt was made to attack Warsaw; that is, from the right bank of the Vistula, the besiegers would be threatened by Novogeorievsk and Sierock. The same was the case with Novogeorgievsk, which was covered by Warsaw and Sierock; while Warsaw and Novogeorievsk served the same purpose for Sierock.

This covering and defence could be all the more efficient and direct, inasmuch as the distance from fortress to fortress could be

covered by a march of only two days. As a matter of fact, each of these places was only exposed on its water-front. The other fronts were practically unassailable, thanks to the support from the other points. A formal siege of any one fortified position would hardly be thinkable, unless at the same time siege was laid to the other two, or at least an investment, a blockade maintained, or a very close observation.

The importance of this Polish three-cornered fortress system was still further enhanced by the existence of another three-cornered group in touch with it, facing Germany and Austria on one side, and on another side Austria. This triangle has two points on the Vistula, namely Warsaw and Ivangorod, which are from 90 to 100 kilometers apart. The third corner is Brest-Litovsk on the Bug. This is 180 kilometers distant from Warsaw and 140 kilometers from Ivangorod. These three points are direct supports of one another, while indirectly they serve as supports for the smaller triangle.

Warsaw and the fortresses of the Russian western front were abandoned by their defenders because of the operative break-through by the Central Powers in 1915, which made possible the advance of the German-Austrian forces. Some of these, as was Novogeorgievsk, were forced by bombardment to surrender, or at all events to be evacuated. As a rule, however, these positions yielded so readily, that it even gave the impression that this course was dictated by the Russian High Command according to a deliberate and predetermined plan. So it certainly leaves one very much in doubt whether the course pursued was entirely of free will, or whether there was a certain amount of constraint, arising from the fact that through the failure of the legislative to provide sufficient appropriations, the character of the constructions and the armaments thereof did not come up to what was really necessary, thereby compelling their abandonment.

A striking exception was found in Ossoviez, situated on the Nieman-Bobr-Nareff line, which, thanks to its situation in the midst of swamp and moorland, was able to offer an extraordinarily long resistance to the German artillery. As the Germans in the year 1914 failed in their attempt to surround this fortress, they brought up a lot of heavy ordnance against it—there is mention even of 42-cm. howitzers—and yet the Russian batteries were so skilfully disposed, that the enemy artillery was unable to locate

them. The Russians succeeded, without themselves suffering material loss, in reducing to silence several batteries of their adversaries. As warm weather set in, it became extremely difficult to emplace the heavy artillery in the swampy district. The fortress fell on the 22d of August, 1915, on account of the general retrocession of the entire Russian front consequent on the capture of Warsaw.

BUCHAREST.

Bucharest, like Antwerp and Warsaw, was counted among the greatest fortified places to be found in Europe. For the drawing up of the requisite plans Rumania obtained from Belgium the services of General Brialmont, the creator of the Belgian fortified regions, and under his direction arose practically all of the fortifications of Bucharest during the period from 1885 to 1896.

Although the Rumanian fortifications were primarily erected as a defence against Russia, yet the presence of Brialmont in Rumania served at that time to stir up a bad feeling in Austria. It suspected in this an unfriendly attitude on the part of Belgium, and insisted on the General's retirement, which feeling, however, was only for the time being.

As with the Belgian fortification system, especially that of Antwerp, the fundamental principle in the defences was the establishment of a strong belt of forts with intervening batteries and works, where the guns were disposed of in domed armored shelters, or protected by other forms of armor. To these were added armored towers transportable or moveable, equipped with artillery, whose mobility was facilitated by the laying of tracks about the whole range of fortifications.

In providing this defensive equipment there arose a sharp competition between the German and French plants for the manufacture of armor plating and ordnance, and thorough tests were made of the products of one and the other, especially of guns against armor. Finally the German establishments of Krupp and Gruson held the field, so that the whole defence outfit, along with its equipment of guns, was practically the output of German houses.

Since Bucharest, with an area, including its outskirts, of about 30 kilometers square, is built on ground that is level throughout, offering nowhere a point that would be in a military sense of a commanding character, the girdle of forts, from 6 to 9 kilometers

distant from the city, had to be of necessity of considerable extent. The circumference was about 75 kilometers, over which were distributed 18 forts, these being almost exactly 4 kilometers apart. In the intervening spaces there were 18 auxiliary works, so that on the flanks only 2 kilometers had to be covered. There was no central citadel, although plans had been made in anticipation of such a structure; likewise, as an additional protection against an attack in force, they had figured on erecting a polygonal wall surrounding the city, 30 kilometers in extent. Between the exterior belt and the city there was also a line to be established equipped with mobile batteries. All of these would require a considerable garrison, at the least from 80,000 to 100,000 men. The armament, as has already been noted, would consist of about 60 armored towers for 15-cm. and 12-cm. guns, of over 70 armored carriages for 21-cm. howitzers, and a great number of disappearing-gun carriages for rapid-fire pieces. In addition to these was to be counted about 400 long and short range guns as an artillery reserve.

Bucharest, whose military importance as lying centrally between the Danube and the Transylvanian Alps, and as being also the nucleus of communicating lines between Transylvania and the head of ship navigation, and where were located the principal munition plants of the country, like the greater portion of the Russian fortresses was not fated to be put to the proof by actual test. So there it was never demonstrated whether the Brialmont system would suffer the same catastrophe as in Belgium, or whether the German-made material on the Dimbovitza would be better able to withstand the fire of the German and Austrian heavy guns, than the French-Belgian on the Sambre, the Meuse, and the Scheldt. The prospect, after previous experiences, did not promise to be very good. At Bucharest, as far as the armor-protected artillery was concerned, they relied largely on the slight probability of the domes being perforated by the enemy projectiles. But with the enormous power of impact of the present-day charges, it is well known that it requires nothing more than to strike the cement envelope of the armored structure in order to wreck utterly the adjusting and disappearing mechanisms of the guns, so that their further availability in action, despite their covers, becomes an impossibility.

One of the greatest disadvantages of the Bucharest fortifications was the open character of the surrounding country, and the

absence of supporting points, which conditions demanded a garrison that only a considerable army could supply. Under the twofold pressure from the Transylvanian Alps and the Danube it was felt that the position was untenable, that a blockade, with eventual loss of the place was to be apprehended. It was accordingly decided, while there was still time to do it, to dismantle and abandon the works, conveying all that was movable of the guns and armor material to the line of the Sereth.

The conclusions, arrived at by the General Staff of the United States, are given in the before mentioned periodical.

The failure of the forts in the present war has resulted from various causes:

1. Where they had been built some years before the outbreak of the war, their plans and armament were all known to the enemy; and for this reason any advantage derived from concealed emplacements was lost. Just as soon as the distinctive character of any element was discovered, guns would be especially designed for its destruction.

2. Their ordnance was not up to date, and was far outclassed by guns of the latest design, which were used against them by the enemy, and with whose character the defense was entirely unacquainted.

3. The garrison permitted the enemy to set up their guns at a distance which was entirely outside of the range of their own guns.

The advantage of covered emplacements was illustrated on the part of the defenders during the siege of Ossoviez, and in the unsuccessful attempt of the Central Powers against Verdun.

The experiences of the present war reaffirm the lessons learned from the siege of Port Arthur in 1904; namely, that the placing of heavy guns in a fort to oppose the enemy artillery was an error. It would apparently have been much better to have emplaced the heavy guns of position in the batteries which lay behind the line of forts; for the protection of these is better subserved by a covered gun-pit than by stone walls or any similar shield. The forts themselves—it is immaterial whether they are permanent structures or have been first erected after the outbreak of war—should serve only for the infantry garrison, and the main line of defences should consist of a series of communicating trenches, equipped with machine guns and lying beyond the line of forts. The forts should serve principally as rallying points for the organization of a counter-attack in case the front line should be broken through.

In order to check the advance of the enemy before he can bring his heaviest guns within striking distance of the city, of a port of entry, or any other important approach which it is requisite to cover, there is needed a garrison of preponderating strength, which will hold the ground in advance of the line of forts. Their activities need to be supplemented by the use of far-reaching guns, which in caliber and range should exceed those ordinarily employed in field service.

The guns of the fortress, both those of position and those that are mobile, must command a broad expanse, and be available for covering as far as possible the entire terrain. It must not be forgotten that the guns permanently set in position can only constitute a small portion of the defensive outfit, or in other words, that the principal reliance must be placed on moveable pieces, of which some at least must be so heavy that the enemy could hardly bring the like into action.

The fortress of the future must embrace an extensive area, so that there may be afforded the greatest freedom of movement to the troops and the artillery. In its elaboration masonry work and armor should serve but a subordinate purpose. Permánent gun positions only need to be constructed on commanding points for the purpose of hindering or preventing the ememy from getting his heavy guns into position. Movable guns are best emplaced behind earthworks, and so hidden from the observation of the enemy that they cannot be assailed by direct fire. It is to be noted particularly that a more prolonged resistance can be offered, where the garrison is strong enough to furnish a mobile contingent of troops, as well as to maintain a mobile artillery, in order to prevent a rupture by the enemy of the line, or his penetration to the city or any point of support. Judging by the experiences of the world war it appears that shelter trenches, with disposable bodies of men and guns, can furnish a better protection than can be afforded by any fortress erected according to the rules of modern art.

It is not our place here to subject these American conclusions to a searching criticism. That has already been done in some of the preceding passages of this article. Their pronouncements only show—and that for our purpose is the main thing, and what our whole essay has endeavored to present—how elusive and many-sided are the views concerning the value of fortresses and fortified places, their location, their principles of construction, their

artillery equipment, and how widely they differ from each other. And this is a warning to us also *not to allow ourselves to be tied down to some one-sided foreign scheme, but after considering the great leading opinions as to systems of land defence, to adopt that which fits in best with the peculiar topography of the country, and agrees best with economic conditions and military requirements.*

This whole article would have to be regarded as incomplete if it failed to present the views and opinions of the representative of the Chief of the German General Staff, Lieutenant General von Freytag-Loringhoven, given in his latest work "Deductions from the World War."

While he notes that along with the constantly increasing employment of the heaviest guns, of flat and of curved trajectory alike, resort has been had in east and west alike of field entrenchments along with barbed-wire entanglements, works which are possible to throw up with the greatest despatch, inasmuch as among such enormous masses of men those skilled in every kind of industry are available for service, so the works have become more and more elaborated along every line of modern art, he then—to quote his own words—continues:

"In connection with the amazing successes won against the Belgian fortresses, and later on against the Russians, through the agency of our own heavy ordnance, and by the Austro-Hungarian motor-mortars, the opinion has been steadily gaining ground that in future a highly organized and strengthened form of intrenchment will replace the fortress. As far as the latter is concerned the fact is patent that the older styles of fortresses have become entirely worthless, that furthermore the earlier traditional view—mediæval as it is—that the secure possession of any section is assured by its permanent fortresses has been abandoned. It has been relegated to the limbo of exploded theories. As far back as 1809 Napoleon said in his Notes on the Defences of Italy: 'Like cannon, fortresses are only a kind of weapon, and may not fulfill their purpose if left to themselves. They must be employed and handled as accessory instruments. In 1806 he had written to the same effect that for the laying out of fortified works the same principles must hold good as for the disposition of troops. Fortresses have, therefore, their place in operating and since the course of these is not to be prevised with absolute certainty, so it

would seem that in the planning of the same the dispositions should be such as to utilize the former most advantageously.

"This, however, seems to be an extreme view. It is certain that previously arranged and strong supporting points, in positions where the defence will probably center, can not well be dispensed with. What the worth of these may be can be learned from the fortifications of the French eastern front, especially from those of Verdun and of the Moselle line. If the weakly manned fortresses, with broad spaces intervening, of the eastern frontier of France, as they were in 1914, were characterized by those of the Allies, who were opposed to an invasion of the country from that side, as the unassailable front of that region, they most certainly exaggerated. If true then it would be as true a hundred years later. However, at Verdun, the tremendous power of our heavy, even of our heaviest artillery, was not able to render their works, taking the same as a whole, accessible to storm; a proof that skilfully laid out and sunken works, where every advantage has been taken of the configuration of the terrain, must prove of great value in the future as in the past.

"And so the fortifying of great cities may be regarded as a thing of the past. As a matter of fact they have long since lost their importance as the core or heart of a defensive system; and in future can only be regarded as convenient and secure shelters for troops in the make-up of a defensive zone. Beside this, and more remotely, they may have a value as storage bases for necessary material, where on any particular portion of the frontier there may be established a chain of permanent fortifications, erected in time of peace, with the end in view of throwing up additional defences against an attack on the outbreak of war. This would not imply the covering of the entire boundary, which would be called for only in case of a war that was in great part stationary in character, such as the manifold exigencies of the present world conflict have necessitated; but rather a chain of vital defence centers, and these again not in the shape of fortified cities, but of well-armored points of vantage. The world war has on one side confirmed anew the principles that the determinative value of a campaign consists in an offensive, and that a war of maneuvers, not of positions, should ever be the constant aim. On the other hand, there has been demonstrated the enormous strength which a well considered system of intrenchments will add to the defensive, a

recognition which has proved of the greatest value, particularly in the geographical conformation of our center."

From all of these citations, these instances culled from the history of war, their consideration and discussion, and from the deductions arrived at, there present themselves as our guides under existing conditions the following view-points and conclusions:

The system for the future fortification of Swiss territory must consist in the creation of fortified zones conformable to the permanent structures already erected in time of peace, and to the established centers of activity provisionally determined during maneuvers.

Such system must not be fettered by adherence to any accepted scheme, but must depend for its standardization upon the topographical, economic, and military conditions and possibilities of the country.

As a fundamental principle it must ever be kept in mind, in how brief a time any method of construction and armament becomes obsolete; and furthermore that in the organization of the forces and the constitution of the staff the army, in case of an outbreak of hostilities, must ever maintain an essentially defensive attitude.

THE FUTURE OF PERMANENT FORTIFICATIONS.[1]

Translated from the French
By

Capt. C. Beard,
Engineers, U. S. Army.

The taking of Liege and Namur, the easy investment of the entrenched camps at Anvers,—all fortified places organized under the direction of one of the most renowned military engineers, the Belgian General Brialmont,—the brief resistance of several French and Russian fortified places (Maubeuge, Manonvillers, Brest-Litovsk, . . .) gave rise to many commentaries, more numerous because certain of the places were counted as among the strongest of Europe.

Though some commentators went to the extreme of proclaiming the failure of permanent fortifications, others, citing the heroic defence of Verdun and that of Przemysl, contested such radical judgment.

It has been deemed of interest to summarize several articles which have appeared in the foreign press among the military journals.

I. One of these articles, entitled "New and Old Reflections Upon the Value of Permanent Fortifications and Defensive Organizations," may reflect in part the ideas of our enemies; it was published in the "Swiss Journal of Artillery and Engineering." (*Schweizerische Zeitschrift für Artillerie und Génie.*)

II. A second article which appeared in the "Memoirs of

[1]This article, which is a translation of a bibliographic review of the subject made by a French writer, is presented in view of the importance of the topic. It may serve to give to the interested reader a more definite notion of the relative rôle played in the late war by permanent and field fortifications, and will at least serve to put him in touch with the opinions of the future of the art of fortification as held by some foreign military writers. No responsibility is taken for the opinions expressed, and the article is presented solely as a review of the current literature of the subject.—Translator's note.

the Spanish Military Engineers'' (*Mémorial de Ingenieros del Ejercito*), under the title of ''Reflections Upon Permanent Fortifications,'' gives a somewhat restricted discussion of the question.

III. Finally, in a paper published by the ''Bulletin of the Hollandish Society for the Study of Military Science'' (*Organ der Vereeniging ter beoefenning de Kryswetensshap*), and bearing as title: ''The Importance of the Organization of the Ground in Open and Position Warfare''; the author has summed up the conditions which future permanent fortifications should fulfil.

I.

The Monograph in the Swiss Journal is evidently inspired by an article which appeared in Germany in the ''Military-Technical Review for Officers of all Branches'' (*Kriegtechnische Zeitschrift für Offiziere aller Waffen*), and also by a work published in the same country: ''Consequences of the World War'' (*Folgerungen aus dem Weltkrieg*), the author of which is Major General von Freytag-Loringhoven, General Staff of Garrison Troops.

He refers to an article which appeared in the *Field Artillery Journal, U. S. A.,* and which seems to be an article emanating from the War College, General Staff, U. S. Army.

In common with the *German Military Technical Review,* the Swiss article commences by defining what is to be understood by the ''modernity'' of permanent fortifications:

''A fortress can not claim modernity unless—

''Its works, as much by their location as by their grouping, conform to permanent tactical principles;

''Its facilities for combat, from the point of view of artillery and engineering, and its sources of supply, give it an indisputable superiority over the enemy artillery and engineers;

''Its works possess, by reason of their construction, a passive force of resistance, superior to the forces with which the attack is provided;

''Its combative power is such that the assailant can not overcome it with the means at his disposal.''

These principles presented, the Swiss articles, still following the German version, criticise severely the rôle played by fortified places during the war.

''Neglecting the element of surprise due to the unexpected use

of a 420 mm. shell,'' says the article, ''neither the masonry nor the turret armor were able to oppose a continuous resistance to the destructive means actually employed in the siege, for the fortresses which were besieged had been built for a number of years, and could not be considered from any point of view as 'modern.' From the tactical viewpoint, their organization did not present the characteristics of other than an out-of-date scheme, and showed other faults also . . . Similarly, from the technical viewpoint, the fortresses were not first-class, neither in point of concreting nor in point of armoring.''

The article adds that these fortified places,—which in the second half of the 19th century, were capable, by their resistive strength and integral means of combat, of defying the assault of any assailant,—were found to be antiquated upon the appearance of rifled mortars, and became more and more antiquated, as the destructive effects of the artillery was increased. In this connection the article cites the case of Anvers, and it brings to notice that it is precisely the strength of the above mentioned places which was responsible for the impetus given to the development of the artillery.

The article explains as follows the causes of stagnation in the development of fortifications, to keep pace with that of the artillery.

''The art of fortification was obliged to seek new means of resisting the power of the assailant, which was increasing more and more; little by little armor became an important factor in the construction of fortresses. But the page had been long since turned. The strength of defenses having given impetus to the creation of new means of attack, the proper hour had been passed. It was now the means of attack which governed the requisite strength of fortifications. Thus this interaction between the means of attack and the strength of defenses, reduced the question of the construction of fortifications to one of money, and since the requisite sums became exceedingly large, the parliaments of all the countries of Europe raised with difficulty the credits which were demanded of them, so that finally military engineers were forced to continually adopt compromise measures.

If in politics and in financial economics, the above is to be tolerated, such is not the case from the military point of view: In war only the *best* and *most certain* have value: ''Insufficiencies and compromises must be avoided since *compromise* only serves to increase *insufficiency.*''

The German writer in the *Military Technical Review,* opposes his opinion vigorously to that of some who, taking example from what happened at Plevna, think that permanent fortifications can now be replaced with simple trenches and who express themselves thus:

"See the trenches upon the field of battle, they cost nothing, they require nothing, and they render more service to their constructors than fortresses."

Evidently, trenches can well, in certain cases, supplement permanent fortifications, but they never can replace the latter, and the writer adds:

"When it is demanded that fortresses be abandoned as such,—located in some cases without reason throughout the land, and existing only because they have existed for centuries, even though they have no longer any reason for existence,—it is indeed proper. Fortresses can be accorded value only when they fit into the whole scheme of defense of a country, and only when they are really modern. But since political formations and military ideas are subject to change, *the defensive system of a country, instead of being founded upon fixed conditions, must be prepared for all eventualities.*"

After opposing himself as above to those who believe in the failure of permanent fortifications, the author gives vent to some ideas on the subject of the *modern fortifications of a region.*

While upholding the utility of isolated fortifications constructed near the frontiers with a view of fulfilling a special purpose, he sets forth the principle that today, particularly with frontiers largely exposed naturally, there is no longer an effective support for the field armies and for the absolute defense of the country except as provided by a system of fortifications built in liaison with extended obstacles, passive, impassable, natural, or artificial, and placed as near as possible to these fortresses.

To this end it will be neceessary as a means of permanent fortification, to arrange in advance, battle terrain, in which the offensive can be freely developed, but where the enemy offensive will meet with a shattering check. The most essential condition would be to have solid flanks. If there are natural obstacles available, this condition would be perfectly fulfilled, otherwise it would be necessary to create them, either by a system of artificial water courses, or by the reforestation of vast zones of woodland which

would extend between the prepared zones of operation, and would constitute in extended depth an impenetrable thicket. Better still, woodland and swamp might be combined, with the object in view that between the prepared zones of operation would lie regions impassable to troop movement. It follows naturally that this system of defense should be carried as near to the frontier as the tactical situation will permit, in order to save as large a portion of the country from enemy devastation.

"If a recognized master of the art of fortification has said that field fortification 'is tactics written upon the ground,' it is a truth so exact that it may be applied for the strongest reasons to permanent fortifications, for the statement has no other meaning than the following: 'The permanent fortifications of a system prepared in advance, should be adapted to the exigencies of tactics, just as well as should be the positions taken on the field of battle through the medium of nonpermanent works.' "

It follows that all formal designs, all reminiscent thought of a diagrammatic layout should be rejected.

"The military engineer should know what are the problems to be solved in the zone considered, following which he decides, according to the tactical object and the nature of the terrain, the location and kind of organization which should be adopted. From the technical point of view he will have certain principles to observe. All constructions which take into account these principles will be correct, if they are adaptable to the terrain in the least apparent manner. It follows then that the military engineer must endeavor to disembarrass himself of the old formulas, and adapt himself to new methods . . . Under actual circumstances, where formidable methods of artillery attack must be reckoned with, as well as aerial and engineer operations, there is no longer any old type possible,—to the rear with the old and superannuated."

Having thus presented the conditions of the problem of fortification, the author enters into the details of execution.

"It will be decided, in each particular case, how much should be prepared in advance, offensive and defensive battle positions, having supported flanks. Groups of fortifications as well as lines of fortifications will be considered, as both of these methods of fortification are justified in use if there is a close relation between their tactical rôle and the terrain . . .

"In both cases, in order to hold stubbornly the zone of opera-

tions, and economize the defensive forces, it will be necessary to try and build strong works, well armed, capable of sustaining the assault, solid and capable of giving rise to effective lines of fire. These works will be the skeleton of the whole series of fortifications; it should not be possible to force one of them until several of the ones in between have been taken. They will serve as support points for local combat, and the intermediate positions will rest upon them as upon solid pillars. These positions will be organized, partly in advance, partly by the troops charged with the defense. Occupied by the infantry they will serve as protection to the combat batteries which would have been constructed, either in time of peace,—well armored,—or as open emplacements, by the troops themselves."

"If lines of fortifications are adopted to resist stubbornly upon the most exposed points, a checkerboard disposition of the works might, according to circumstances, render good service, because thus is obtained reciprocal support and also the greatest possible resisting force. It will be necessary to build redoubts which must remain intact,—when the enemy, having broken through the advanced lines, presents himself before them."

In insisting upon the necessity of getting away from all formal designs and dimensions, and to base the design solely upon the necessities of the case, and upon results of recent experiences the author brings out that the fundamental principles for the organization of modern strong points are as follows:

Strong points should:

1. Permit a crushing fire upon the enemy in close combat, and also up to the extreme limits of close combat;

2. Give fire crossing with that of adjacent works, and be provided with batteries and flanking organs;

3. Present a strong resistance in case of assault;

4. Forbid to the enemy his occupation of such works as he might overcome.

In that which concerns the first principle, there are no other means, in the actual case, than the following:

a. Protect all the defensive forces by heavy armorings.

b. Make invisible the combat organizations.

On this subject, the German writer, author of the article in the *Military Technical Review for Officers of All Arms*, make the following comments:

"In works which are provided with an unprotected firing parapet, it will be necessary during the bombardment which precedes the assault to keep the garrison in bombproof quarters. This garrison, as soon as the artillery displaces its fire, will rush to man the parapets to resist the expected assault. The men will issue but slowly from the narrow passageways to the subterranean shelters, hermetically sealed, and provided with tortuous passages to protect the occupants from the blast of explosion of mortar shells of large calibre. According to the length of parapet demolished by projectiles, the condition of the parados and traverses, and the shelters beneath the parapet which will have been demolished, the rapid occupation of the firing crest will be difficult and the control of the officers over the men, and their control of the fire, will be made almost impossible."

"If the garrison is brought to the parapet by a feint, and while there is showered with heavy trench mortar projectiles, it will be obliged, in a decimated condition, to again seek its shelters through a labyrinth of shell holes, only to be soon recalled to the defense by a new alarm."

"And if by a single round reaching its objective, a shelter is demolished with its occupants, a certain irreplaceable portion of the defending troops is lost."

"Troops, thus thoroughly demoralized will falter at the moment of assault."

"Moreover the protection secured by fire from neighboring works, is impossible at a time when friend and foe may come under it at the same time. On the contrary when the attacking artillery has gained fire superiority it is the defensive infantry with its machine guns which becomes of first importance. It is indeed these troops who have in their hands the decision."

"It follows therefore that the strength of the defending troops must not be diminished by premature losses, and it must be in a condition to steel its nerves when the enemy advances to the attack."

"The duty of the military engineer is to organize the works in such a way that the defender, not yet demoralized, but intact, can come into action at the opportune moment, and the defender then is sufficient unto his task if he is well armed. If he is denied proper weapons at the decisive moment, he can not be counted upon."

In conclusion, to meet these requirements adequately, there is only one definite means:

"Everything armored, no more open emplacements."

"For this a great deal of money is necessary, and this money must be appropriated if fortifications are desired which are really capable of resisting."

The author examines the question of armoring, which is of course susceptible of several solutions.

"It is possible in sheltered work to conceive an armored gallery taking the form of the work, and designed to shelter the infantry and the automatic weapons. Such a disposition is perhaps the most advantageous for the control of fire; and it requires for the works themselves only moderate dimensions. But under the actual circumstances, destructions must be localized, and even a solid partitioning will not accomplish this object. In addition, armored galleries do not lend themselves easily to concealment. In all cases, it is more advantageous to build a large number of armored machine gun emplacements, dissimulated in thickets so as not to be very easily located. Preliminary trials, carefully undertaken, will reveal whether these emplacements should be built to rotate, to be fixed, or to be built with a shuttered embrasure. Here, again, the question of expense plays an important rôle, and a solution involving the least expense is not the one necessarily to be chosen, but rather the one which gives the best results."

"The weapons intended for close defense should similarly be placed in armored turrets, made invisible from the outside, and located unequally throughout the works."

"If," adds the author, to whom the notions are accredited, "these dispositions are well taken, such a work could be located neither from above nor from afar, as a work of fortification. It is necessary that the enemy have merely an impression of a terrain somewhat gullied, and partly covered with trees and thickets."

From all this, the conviction becomes absolute that the contest between projectiles and armor—which has so far been decided in favor of the projectile—may continue to evolve. "The man who invents the weapon will know also how to forge the shield."

After having stated that the employment, ever increasing, of artillery with flat and curved trajectory and of large caliber, has caused the transformation into organizations of rather permanent character, the works built at the start of the war with the resources

of modern industry—Lieutenant General von Freytag-Loringhoven, Chief of Staff of Garrison Troops, German Army, proceeds to express himself as follows with regard to permanent fortifications:

"The surprising results of the fire of our curved trajectory mortars, against Belgian fortresses and later against Russian fortresses, has given rise to the thought that in the future the reinforced trench would replace the fortress."

What is really the truth, is that fortresses not modern in the now recognized sense of the word, should be deliberately abandoned as such; as must also the idea that the possession of a place must be assured by fortifications. That idea has long since been relegated to oblivion. As far back as 1809 Napoleon wrote in his notes upon the defense of Italy: *"Like the artillery fortresses are not arms which alone can fulfil their missions; their properties must accordingly be supplemented, and given the correct employment."*

"In 1806 he (Napoleon) gave expression to the idea that fortresses depend upon the same principles as the disposition of troops. Fortresses should assist in operations, and as the nature of them can not be foretold with certainty, it would seem as though the work could only be built advantageously during a war, and then only where needed." This is going too far. The recommendation is not made that solid supporting points be not established in advance at points where it is intended a stand should be made.

"In that which concerns the strength these works should have, the fortifications on the Eastern frontier of France, and above all, those at Verdun and the Moselle line, give us important data."

"To call—as did those who in 1814 argued against an invasion of France—the fortresses of her Eastern frontier, feebly occupied and built at long intervals apart, 'the unattackable frontier of France,' was a gross exaggeration. It became a truth a century later. The powerful effects of our heavy artillery at Verdun, during the attacks, did not render the works easy of assault; which is a proof that fortifications, carefully located and dissimulated, where the nature of the ground is favorable, can have, now as before, a very large value."

"On the other hand, it seems to be out of date to fortify the big cities. They have long since lost their importance as central nucleii for systems of fortifications, and in future they will not be able to claim the rôle, except in the cases where they constitute cantonments in the fortified zone."

It will be necessary later to guarantee the security of certain frontier zones by means of a series of permanent fortifications built in time of peace, and to these will be added, at the opening of hostilities, other works, the material for which will be prepared in advance. It will not be necessary to create a continuous ''Lime''[1] which would only permit of a stratified defensive, such as was imposed upon us in this war by circumstances, but only a series of fortified strong points, not in the nature of fortified place, but rather as important portions of the terrain, well organized in advance.

''The world war has, in part, confirmed anew the old truth that the attack only has decisive importance, and that the tendency must be toward a war of movement rather than a war of position.''

''On the other hand, the world war has shown the enormous strength of a defensive, supported by well organized fortifications, a conclusion of tremendous importance to us (the Germans), given our geographically central position.''

The memoirs from the War College of the American General Staff, which was analyzed by the *Swiss Journal of Artillery and Engineering* give, in that which concerns the future of permanent fortifications, the following opinion:

''The fortification of the future should encompass a large territory in such a way that it secures to troops and artillery the greatest liberty of movement. For this there is no need of masonry and armor in the forts, which is exposed to view. Permanent emplacements for weapons will be established only at important points, to prevent the enemy from then installing pieces of still greater caliber. In these subterranean batteries should be installed mobile pieces, which will be defiladed as much as possible from enemy observation, to prevent their being taken under a direct fire. It must be borne in mind that a long resistance can not be made unless the garrison,—as much from the point of view of the defensive troops as from that of mobile artillery with which they are provided,—is sufficiently strong to prevent the enemy from forcing the lines or from penetrating into the cities or places it is desired to protect. It seems that from the teachings of the present war that

[1]The ''Lime'' was, during the period when the Romans occupied what was then Gaul, a huge protective wall, uniting the middle Rhine with the upper Danube and encircling a large portion of Wurtemberg and of Baden, strong points for the defense, not in the nature of fortified cities, but rather of fortifications of important portions of the terrain.

trenches with mobile troops and artillery offer better protection than fortresses constructed according to a formal scheme.

II.

The article which appeared under the initials C. B. in the *Memoirs of the Spanish Military Engineers* recognized first of all that it is premature to deduce lessons or conclusions from the events of the war because the elements with which we form our judgments are still scarce, and generalizations on conclusions arising from a particular case should be avoided, so that errors of deduction will not be committed.

It must be remarked that the sources of information are somewhat confused. These are official reports, frequently tenacious, the greater part of the time lacking veracity in that they exaggerate that which is favorable, and attenuate that which is unfavorable, or the notes of correspondents who are complete strangers to the military profession. From the standpoint of the national defense, the belligerents are compelled not to divulge during the course of operations reports or information of a certain class.

Under these circumstances it is best before drawing conclusions, about the future of permanent fortifications, to await the conclusion of hostilities, so as to have at hand all information which will permit the formation of a correct judgment. But, nevertheless, it is not forbidden to give consideration to such material as is available and which is applicable to the questions which may present themselves.

First of all, the author judiciously remarks that in order for systems of permanent fortifications to become useless it would be necessary that, at the same time, all causes which necessitate a defense at all price of certain localities whose situation or resources make them desirable to the enemy, should disappear.

In this group are found the large centers of traffic near the frontiers which are necessary to facilitate mobilization; naval bases where are concentrated the elements indispensable to maritime defense: but in addition to these localities, situated on the borders of the state, there exist in the center of the country important positions which it is necessary to defend and today, among these, it is not possible to forget, by reason of the progress of aviation, the establishments destined for the production of war munitions which, although distant from the frontiers, are none the less exposed to aerial attack.

The choice of positions, which necessitates for their defense recourse to permanent fortifications, because they are exposed to the attack of the enemy from the moment of commencement of hostilities, should emanate from the authorities who are responsible for the studies for the National Defense. It is a strategic problem the solution of which depends upon the topography of the country, upon international politics, and upon financial considerations. It is work of preparation for war, which should be done in time of peace.

The execution of the work, as is natural, is incumbent upon the military authority which discusses and proposes all matters regarding the armament and protection of chosen points by carrying out the prescriptions of the military regulations concerning such matters. This authority should study simultaneously the different aspects of the problem from the tactical point of veiw, and from that of the artillery and the engineers.

The writer undertakes to show that under none of these aspects can it be held that permanent fortifications give an unsatisfactory solution and that there is no longer any other recourse than to commit them to oblivion.

(a) The problem from the tactical point of view necessitates a study of the terrain, without which an adaptation of the defensive elements to the ground is impossible. Where it is a question of a field work or a permanent work, the terrain is the governing feature: It is a tyrant to whose demands we must yield, but with a certain amount of caution.

In this adaptation to the ground, the individual who is in charge, can succeed with relative economy in increasing the advantage of the position, and decreasing its inconveniences; it is therein that is found the true art of the engineer. In certain cases this adaptation is not easy. It is clear that it is complicated by the increase in range of the artillery, and in general, by the advances in perfection of armament; but it is facilitated in turn by the greater liberty conceded to the engineer by modern principles of fortification: no more complicated problems of providing defilade, but good sense and intuition replace formula and routine.

On the other hand, it is not to be doubted that the improvement of the artillery, even though it has complicated defensive works by requiring of them better protection, has also contributed to a simplification of the general outline of fortifications. For

example, the bastioned fronts—which during the Eighteenth Century and the commencement of the Nineteenth were the obsession of French military engineers—presented the great inconvenience of rigidity due to the fixed relations between their constituent lines. This fact explains that during the period considered, the problem of fortification was, so to speak, a problem of geometry, so that neither modifications nor progress were manifested.

It was to this stagnation of the art of fortification which may be attributed without doubt,—in the above period,—the limited progress or even lack of progress of the artillery, the two being closely interconnected.

Polygonal fortifications marked an advance by breaking away from the formality which had characterized permanent fortifications; it established a certain independence between the firing crest and the flanking organs and most important, permitted the separation of the defense at close quarters from that at long range.

But the factor which brought about a revolution in the art of permanent fortification was the introduction of rifled artillery. The progress resulting therefrom made it impossible to keep the civil population of an integrally fortified city beyond the range of enemy artillery. For this reason it became necessary to build separate forts placed at intervals depending upon the range of cannon; these isolated forts replaced the towers, the bastions and the flanking capponiers; courtines no longer were continuous and were marked by intermediate works and by batteries. The height of wall became negligible and in certain cases was entirely suppressed. For these reasons permanent fortification was freed from all geometric considerations governing its trace, and the principle of separation of the defense at close quarters and that at long range being established, as well as the existence of a mobile artillery, the problem of the location and the tracing of fortified places no longer differs widely from the principles governing the siting of field fortifications. The one difference, and it is not a strong one, is that in the case of permanent fortifications the line of defense is a closed perimeter and in the case of field fortifications it is constituted by a front more or less sinuous.

Therefore, in that which concerns the siting there is no longer any reason for not applying to permanent fortifications the principles which govern the siting of field fortifications.

(b) The author proceeds then to discuss the qualities of the

artillery. He calls attention to the fact that in an attack on a fortified place, the artillery plays the most important rôle: if one of the combatants possesses over the other an incontestable superiority due to the number of his pieces, to their qualities or the superior instruction of his personnel, the contest will be promptly decided in his favor.

It may happen at the start of a war that there will exist the element of surprise in that one of the belligerents will make use of matériel of a new and unknown character and with which competition will be impossible. Fortifications are constructed to enable a resistance to this eventuality, and this in itself is for them an important function.

Finally, in general, the improvement of the artillery precedes that of fortification: fortifications are then the consequences of these advancements, and it is much easier to change the armament of an army than it is to make important changes in the construction of fortified places. These changes frequently are only made imperative by costly experiences which reveal the faults which must be remedied. But there is no reason why the improvement of the artillery should not be useful to the defense as well as to the attack. Truly, pieces of large caliber may well be installed in prepared emplacements, under better conditions than in improvised emplacements, and the mobility of the pieces will be conserved as well in the first as in the second case.

(c) This established, it remains to know if it is possible, by means of what may be called military architecture, to give to the structures a sufficient strength. Herein occurs the intervention of the engineers. It has been observed that in actual war, the extemporized works constructed upon the different fronts during the course of a campaign, have necessitated for their destruction extensive and prolonged bombardment. But it is very evident that if the permanence of armies in their respective positions upon a stabilized front has enabled these works to be solidly constructed, the conditions for this will be still more favorable if they are constructed in peace time when it is possible to apply even more efficiently the means and materials for their construction.

It is the eternal contest between the projectile and the armor which, along these lines, causes the author to observe that the improvement in naval guns has not caused the elimination of armored ships, but has rather led to the increase in their strength by giving

their armor greater thickness; and by utilizing improvements in its metallurgy giving metals of greater resistance. In particular, the armored battleship is a floating fortress. If upon the sea, the use of these floating fortresses has not been abandoned, there is no reason why, in the operations of land warfare they should also be abandoned.

On the other hand, while in the art of naval construction the engineer has used, up to now, only metals for the protection of ships, the military engineer may employ materials of a more frequent occurrence, by using cement alone, or cement combined with steel, earth work, sand and masonry of all kinds. Thanks to the employment of ordinary concrete and of reinforced concrete, it is no longer necessary to solve complicated problems of stereotomy.

On the other hand, it has never been necessary to construct indestructible works, and the strength of fortified places has always been limited; thus in a good many cases, these places have been sufficiently strong to successfully play the rôle assigned to them, and those which have succumbed to the attack were not always surrendered on account of a fault in their construction, but owing to other causes which had a powerful influence upon their defense.

It is not doubted that when it be possible to study in great detail the defensive works executed by the belligerents, it will be possible to form a competent judgment upon the worth of the different materials employed; by reason of the experience acquired thus and also from tests made in peace time, a set of conclusions will be drawn which will permit the development of a type of construction sufficiently resistant to withstand the fire of modern artillery, but the principle must be well established that in a warfare of position, as well as in naval combat, the principle defensive rôle belongs to the artillery; thus, in order that its efficiency be as great as possible, fortifications must provide for artillery, the protection needed: a powerful artillery, insufficiently protected by cover, may be annihilated by another artillery, inferior in strength but perfectly emplaced. Given equality of ballastic properties, a good overhead cover for an army's artillery may be, and perhaps always will be, a deciding factor in combat.

In conclusion, the author is of the opinion that it is impossible to affirm that the present war will involve as a conclusion, the abandonment of permanent fortifications, the efficiency of which depends on diverse factors which cannot be exactly stated.

According to him, the layout, the armament, and the means of protection are not different for permanent works than are those employed,—with excellent results,—for field works which permanent fortifications approach in character by reason of the time which has been spent upon their construction.

He feels in sum, that there will always be sensitive points needing protection: either at the frontiers, the pivotal defensive points, or in cities, the factories and arsenals—accessories of the national defense,—which are exposed to aerial bombardment.

As final conclusions, the author expresses himself thus:

"To abandon permanent fortifications and announce their uselessness because certain places, for reasons which are not yet well known, did not fulfill their rôles, is a simple matter."

"But when sufficient material will be at hand to form a competent judgment, it will certainly be seen that the modern methods of combat complicate the problem. These methods will necessitate studies and experiments which will serve as a base from which to arrive at a solution in harmony with the progress of artillery and aviation."

"History repeats itself. Since the first introduction of artillery up to the present time several centuries have passed and almost unbelievable progress has been realized. Keeping pace with this, the art of fortification has evolved, and has presented protective elements which, although they do not attain the state of ultimate resistance, oblige the enemy to employ all his offensive means and may make him pay dearly for his progress. This, of course, is precisely the purpose of fortification.

III.

In studying "The importance of the organization of the ground in position and open warfare" the author of the monograph published in the "Bulletin of the Hollandish Society for the study of Military Science," goes into the question of permanent fortifications, basing his conclusions upon the teachings of the war, and expresses the opinion that the following points may be considered established.

(1) "In that which concerns permanent fortifications, the value of tactical principles is universely recognized;"

(2) "The conduct of modern warfare necessitates the abandonment of the existing forms of fortifications, in particular all large isolated fortresses. In the same way, future permanent fortifications cannot be constructed according to a type plan. Forts of huge

dimension and with geometrically disposed elements must give place to studied organizations of the ground following recognized tactical principles; to this end recourse will be had to systems of fortifications, reinforced or strengthened by the employment of the powerful resources which are furnished by modern technical practice.''

(3) ''The general organization of permanent fortifications must in the future coincide with organizations of fortifications in the field. All permanent or field fortifications should also be based upon the following principle: *Increase in tactical value of the terrain by means of the employment of modern technical resources.*

''Summing up; the utilization of the factors; *time, strength* and *technical resources,* as well as the possibility of deploying the entire power of technical practice, to the aid of tactical operations, will permit, with permanent organizations of the ground, to obtain a passive power of resistance much greater than by recourse simply to field fortifications.''

On the strength of these considerations, the author adds: ''From the foregoing I conclude that the construction of forts in the future is strongly recommended.''

Further along, dwelling upon the rôle of permanent fortifications:

''I am convinced that the events of this war have brought out that better use of the existing fortifications might have been made to support the operations of the armies in the field. To form a judgment upon the value which these works might have had, the way in which they were utilized should be examined, as well as their general organization, and the nature of the materials employed in their construction.''

''It is not to be doubted that permanent organizations, positions constructed almost completely in time of peace, will take in future a new place in the defense of a territory than up to the present time they have taken. Above all, they are indispensable to a small country in order that its field army may always be effectively in a condition to restrain the offensive of a great power. In this respect the lesson which was furnished by fortifications on the eastern frontier of Belgium must not be forgotten. Not yet ready for combat purposes, they were not in a condition to stop the formidable attack of the Germans, which fact had a great influence upon the ulterior progress of the war.''

CONCLUSION.

The studies which have been presented have only relative value, and the opinions which are given cannot be considered as definitive, but it may be stated that they all affirm the rôle which permanent fortifications will play in the future. The following is certainly true. If certain fortresses which existed at the commencement of hostilities were not able to oppose to the enemy the resistance which was expected of them; perhaps they were not entirely abreast of the progress realized by the artillery and of the revision of tactical science which resulted therefrom; but above all their function was not sufficiently adapted to the general conditions of modern battle.

The contest is not yet terminated between the projectile and the armor. There is no reason to believe that by paying the price it will not be possible in the future to construct fortifications capable of withstanding the attack of projectiles of large caliber; but the word of Napoleon, already quoted in this article, remains true: "Like cannons, fortresses are arms which alone cannot fulfill their missions."

In detail, the authors of the studies reviewed here, differ in their opinion. They are in accord in stating that the application of tactical principles, and the adaptation of works to the ground are of fundamental importance as much for permanent fortifications as for those built temporarily in time of war.

The American article and the Spanish author express the opinion that factories working for the national defense should be protected by permanent works, at least against the encroachment of enemy aircraft.

The German writers, on the contrary, consider that except in particular cases, the fortification of centers of population is useless.

In that which concerns systems of defense they advocate the preparation of offensive battle fields, separated by large zones of passive obstacles, natural or artificial, in proximity to the frontiers, to protect the greatest possible part of the national territory from devastation by the enemy.

It may be stated that the thoughts of the German authors are none other than those enunciated with us by General Séré de Rivières. After 1870, it was under his direction that the defensive barrier of our eastern frontier was established. This barrier incomplete as it was in 1914, without doubt was not without influence upon the enemy in the grave decision which he took of violating Belgian neutrality; this in spite of the formidable siege material with which he was provided, to enable him to force this barrier.

CURRENTS AT AND NEAR MOUTH, SOUTHWEST PASS, MISSISSIPPI RIVER.

By

Mr. T. E. L. Lipsey,
Assistant Engineer in Charge.

Complying with instructions contained in letter from the office of the Chief of Engineers, dated September 27, 1916 (E.D. 30157), concerning the making of observations on flow of currents in South and Southwest Passess, I have to submit the following report on current observations at and near the mouth of Southwest Pass:

(*a*) Seven complete sets of observations, two of surface and five of sub-surface, were made in the Gulf beyond the ends of the jetties at Southwest Pass, during the period from October, 1916, to September, 1917. Each set consisted of from sixteen to eighteen observations of currents at depths varying from 0 to 90 feet below the surface, and at properly distributed points in the area stated above. Paths of these currents have been drawn to a scale of 1 to 224,000.

Besides the seven sets of observations previously mentioned, four complete sets, one of surface, and three of sub-surface currents, were made in the same locality in the spring of 1916 for the consideration of the board in connection with its report of August 8, 1916. In connection with these observations, 69 water samples were taken at depths varying from 0 to 40 feet below the surface at various points in the same area, and their specific gravity, temperature, and other characteristics observed.

Six observations of surface, and twenty-one of sub-surface currents were made in this locality in the spring of 1915, in connection with a study of the subject. A set of ten water samples was also taken at this time at various depths, at, and immediately beyond, the ends of the jetties.

It was thought advisable to consider the results of all of these observations, together with the seven tests lately made at the board's direction, in order to present the maximum amount of

data for consideration in connection with a study of the subject. In order to afford a convenient and concise means of studying the matter, the results of all of these observations have been redrawn to reduced scale, and these drawings, together with other data bearing on the subject, are presented in a series of tracings 10½ by 16 inches, the prints of which can be bound in book form for easy reference. Some data has been added in the tabulations on the sheets showing the paths of the currents, which, it was thought, might bear on their cause. The tracings pertaining to observation in the Gulf are 48 in number, the matter of each is explained by title and notes, and they will be referred to in this report by their sheet number.

On sheet No. 1 is shown the lower reach of the Mississippi River, from Point A La Hache to the Gulf, with the general contour of the coast line and of the 6 and 30 foot curves beyond the delta.

The floats used in making the observations are shown on sheet No. 2. For the surface currents, a built-up timber float, octagonal in plan, 3 feet wide, built up of 1-inch boards on 29 by 4 inch strips placed diagonally and around the perimeter of the octagon, was used. The float was therefore effected by the surface layer of water 5 inches thick. This float was made as large as could be conveniently handled in order to present as great an area as possible to the current, and reduce to a minimum the effect of the wind on the small staff and flag necessary to make it discernible in the water. The total area presented to the current was 180 square inches, and the area presented to the wind 6 square inches. Since the flagstaff was round, and therefore, the wind pressure only about 60 per cent of that on a flat surface of the same section, the ratio of the effect of the wind to that of the current, on the float, was probably about 1:50.

In some of the earlier observations, a board $1'' \times 12'' \times 4'$, with a small signal flag was used.

For the sub-surface currents, 2 pieces of heavy tin 15 by 18 inches, bent at right angles and riveted together and braced with wire, as shown on the drawing, were used to form the sub-surface "float." A small weight was attached in order to maintain it in as near a vertical position as possible during the observation.

This "float" was supported at the required depth by means of a fine braided line attached to a surface float which consisted of a hollow oblate spheroid of light copper 10 by 7 inches, on


89° 30'
89° 00'
Grass Pt.
Gardners Pt.
Mozambique Pt.
BLACK BAY
PT. A LA HACHE
BRETON SOUND
Little Battledore I.
Battledore I.
CALIFORNIA BAY
California Point
Hog I.
Little Bird I.
Breton I.
Errol I.
12 ft.
18 ft.
30 ft.
True North
Empire
Sable Pt.
Sable Is.
Bird I. Sound
Venice
MAIN PASS
Bull Bay
Blind Bay
Oysterville
Garden I. Bay
Port Eads
East Bay
6 ft.
30 ft.
WEST BAY
Burrwood
SOUTH PASS
SOUTHWEST PASS
GULF OF MEXICO
SHEET NO. 1
MISSISSIPPI RIVER
POINTE A LA HACHE TO THE GULF
SCALE
89° 30'
89° 00'

which was placed a small staff and signal flag. This shape of float eliminated any impact of the surface current, the only effect the latter could have on the surface float being that of "skin friction," which is almost negligible. With the sub-surface "float" attached, the upper float was immersed to a depth of about 4 inches. With this arrangement, it is obvious that the effect of the wind and surface current on the movement was very small compared with that of the sub-surface current. In the earlier observations, the surface float consisted of a prism of cork 12″×6″×5″, but the float just described was later substituted in order to reduce to a minimum the effect of the surface current on the movement of the float.

In making the observations the floats were dropped from the tug at the desired starting points and located at intervals of from 15 to 45 minutes. Locations were made by sextant readings to fixed marks on shore and by ranges on shore whenever these were available. Each location was determined by two angles and checked by a third angle and by ranges whenever possible. A protractor was arranged with the circles representing the loci of points, subtending equal angles from the fixed points on shore and with all available ranges drawn in, and on this the locations were plotted on the boat as the observations were made. In this way from 2 to 6 floats, started from different points, could be followed at a time by one party.

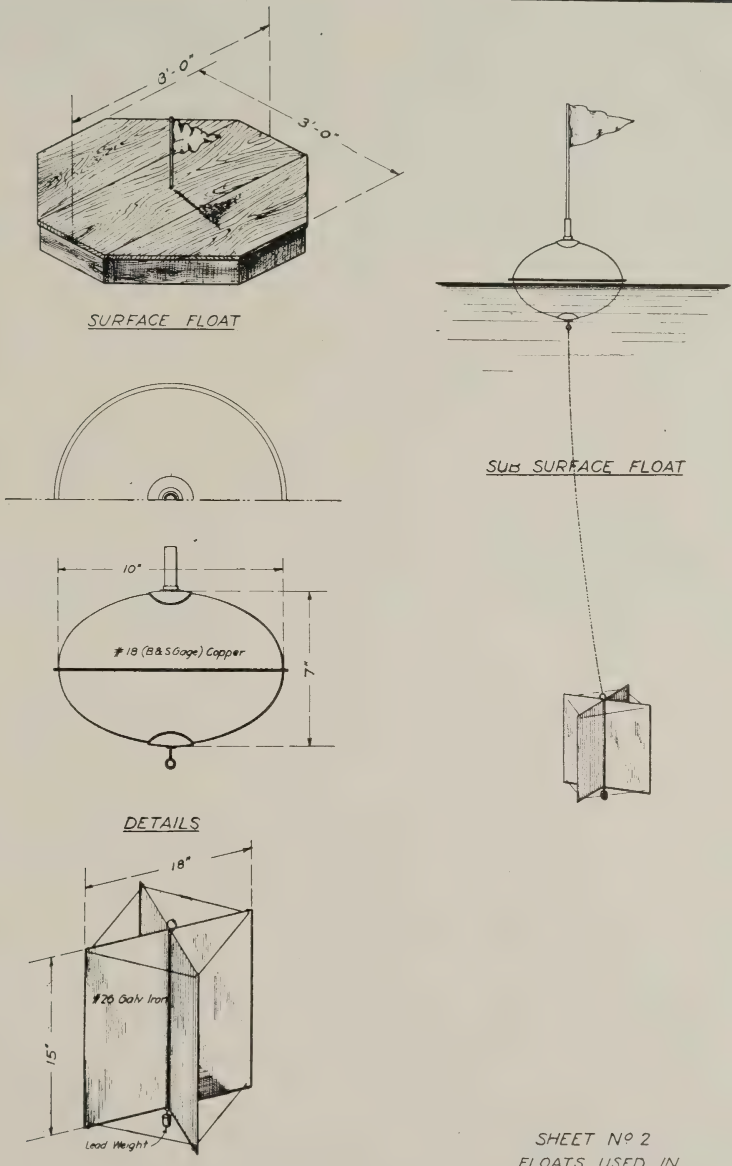
On sheets Nos. 3 to 6, inclusive, are shown the paths of all surface currents observed, each sheet representing a complete set of observations made in the period noted. The tabulations give all the data that it was thought might bear on the subject.

On sheets Nos. 7 to 12, inclusive,[1] all observations started from the same point, but made on different dates and under different conditions, are grouped, and the same data as given on the other sheets is tabulated.

A casual study of this data invites the deduction that the direction of these currents conforms to the natural spread of the river water as it emerges from between the ends of the jetties, modified by the wind during the observation.

On sheet No. 13 are plotted all observations that were made in calm weather or during northeasterly winds which blow almost directly along the axis of the outflowing water. In order to com-

[1]Sheet No. 7 only reproduced.



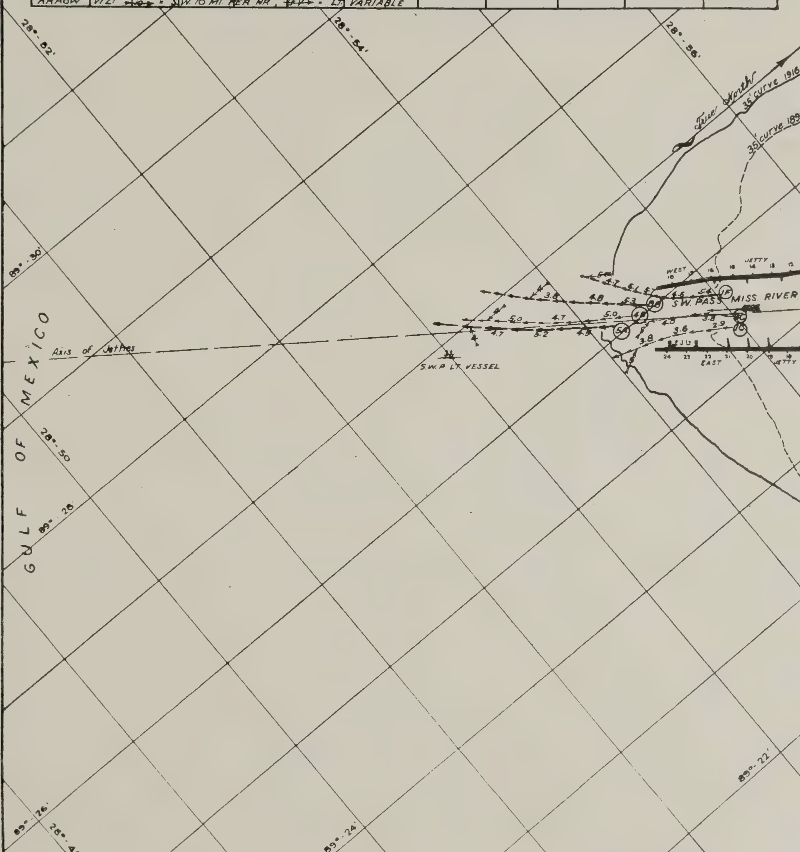
SHEET No 2
FLOATS USED IN
MAKING OBSERVATIONS

pletely cover the area, other lines of currents were interpolated from the actual observations. It is believed that the ensemble represents very closely the actual distribution of surface current flow when the wind influence is eliminated; that is, the ''fan-like'' spread so often referred to in works on or akin to this subject. Beyond the effective area of this fan, or where the energy of flow due to jetty confinement was feeble, it was noticeable, even during the observations, that the current was almost always nearly in the same direction, or apparently plainly influenced by the wind during the observation. Observations Nos. 3 and 4 on sheet No. 4 show this clearly, for although the wind was light, a shift from Northeast to Southeast changed the direction of the current by nearly 90 degrees. Floats Nos. 9 and 10 on sheet No. 5, during a moderate East to Southeast wind, traveled West by North across the face of the jetties. Floats Nos. 6, 7, and 8, on sheet No. 6, during a strong Easterly wind are plainly influenced by this wind, although the effect of the spread of the outflowing water seems to be the stronger influence near their starting points.

On sheet No. 14, the direction of the current and of the wind during the observation are tabulated for all observations that were made, and the relation between them noted. In interpreting this relation, allowance was made for the influence of the energy and fanlike direction of flow due to jetty confinement near the jetty ends, especially during the higher stages of the river when this influence is strong and extends some distance seaward. It will be noted that in this tabulation, as indicated, 6 observations were omitted in summing the results for the reasons that during the observation, the weather was calm, or the wind too light to affect the current, or the observation was made immediately at the ends of the jetties where the float was under the influence of the outflowing river water which was too strong in comparison with the wind effect to permit of satisfactory interpretation. Of the remaining 52 observations, as indicated in this tabulation, in 46, or 88.4 per cent of this total, the direction of the current was plainly in accord with the direction of the wind during the observation; in only 6, or 11.6 per cent of this total, was the direction of the current partially in accord with the direction of the wind during the observation, or it was difficult to decide if the current was influenced to any great extent by this cause; and in not a single observation was the current apparently uninfluenced by this cause.

Float No	Am't of submergence (ft)	Date of Obs	General Direction of travel	Prev wind for 3 days prior to Obs.	Prev. wind for 10 days prior to Obs.	Carrollton gauge (ft) (R S. or F)	Burrwood gauge (ft)	Cond'n of tide R=rising, F=falling, S=Sty	Rate of change of tide in 1/100 ft per hour	Avg vel. of float for 1st 6000 ft of travel in f/s	Avg vel. of float for entire observation
5-A	0	Apr. 27/15	SW'ly	E'ly.	E'ly	780 - S	4.6	F.	10.0	4.9	4.9
4-B	0	" 28/15	"	SE'ly	"	780 - S	4.3	R.	1.0	5.0	5.0
8-B	0	" " "	"	"	"	780 - S.	4.1	F.	10.0	4.5	4.5
7-C	0	May 1/15	S'ly.	Lt. N.W'ly.	"	760 - S.	4.8	R	1.0	3.4	3.4
3-C	0	" " "	SW'ly	"	"	760 - S	4.8	R.	1.0	3.9	3.9
1-F	0	" 10/15	"	E'ly.	V'ble.	780 - S.	4.2	F.	8.0	5.1	5.1

THE VELOCITY & DIR'N OF THE WIND DURING THE OBS'N. IS SHOWN BY ARROWS, THE VEL. IN MI. PER HOUR WRITTEN IN THE ARROW VIZ: —10→ = S.W. 10 MI. PER HR, —VV→ = LT. VARIABLE



CURRENTS FOLLOW ARROW POINT
LIGHT LINES INDICATE RISING OR STATIONARY TIDE
HEAVY LINES INDICATE FALLING TIDE
FIGURES ALONG THE COURSE OF THE FLOAT INDICATE
THE VELOCITY IN FEET PER SECOND IN THAT VICINITY
AMOUNT OF SUBMERGENCE IS INDICATED BY ROMAN NUMERALS
WRITTEN IN THE COURSE OF THE FLOAT, VIZ: X FOR 10 FT, XX FOR 20 FT ETC

SHEET Nº 3
SURFACE CURRENTS.
OBSERVATIONS MADE IN APR. & MAY, 1915.
SCALE

In this tabulation ten observations fall in the "doubtful" column. This number includes the four of this column that were omitted from the totals for the reasons previously stated. In considering these ten observations, especially where calm weather or light winds obtained at the time, it is most logical to suspect that the wind immediately prior to the observation was the controlling factor for the direction of the current. In this connection, a tabulation has been prepared, and in numbered sheet 15,[1] which gives the direction and intensity of the wind for several days prior to these observations. . . .

. . . .

. . . It appears, therefore, from a careful study of the data that the direction of the surface currents beyond the jetty ends is governed by the natural spread of the outflowing river water which obtains its energy from the jetty confinement, and the direction and intensity of the wind during the observation. If this latter is light, or calm, then the wind immediately prior to the observation appears to be the modifying cause. Beyond the influence of the issuing river water, the direction of the surface flow is almost entirely governed by the wind.

In this tabulation it will be noted that in only 9 of the 52 observations considered, or 17.3 per cent of this total, was the "set" of the current to the East of the channel axis, while in 43, or 82.7 per cent of this total, the current was to the West of the channel axis. It is seen from the table that in practically the same ratio was the wind from directions opposite to these during the observations, or the wind had a prevailing Easterly direction, from which we would expect a prevailing Westerly "set." The prevailing Westerly set is also caused in some measure by the layout of the outer works, which were designed especially to throw the surface flow, which carries a large part of the river sediment, slightly to the West of the axis of the outer channel and thereby prevent this deposit in the prolongation of this axis.

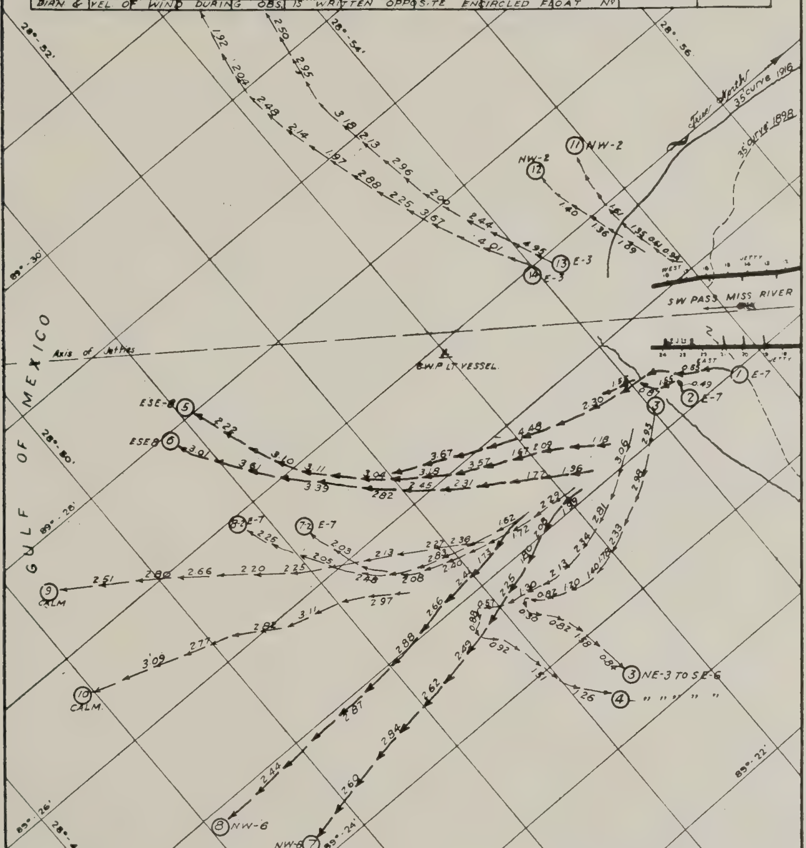
Having established the fact that the wind is the main controlling factor in the direction of the surface flow, it is now necessary to determine the prevailing winds at the mouth of the river, in order to ascertain the prevailing direction of this current. On sheet No. 16, the wind chart for Burrwood, about 5 miles above the ends of the jetties, for the fiscal year 1916-1917, is shown.

---

[1]Not reproduced.

Float No.	Amt of submergence (Ft)	Date of Obs	General Direction of travel	Prev wind for 3 days prior to Obs.	Prev wind for 10 days prior to Obs.	Carrollton gauge (Ft) (R S or F)	Burrwood gauge (Ft)	Cond'n of tide R-rising, F-falling, S-Sty	Rate of change of tide in 1/100 ft per hour	Avg vel of float for 1st 6000 ft of travel in f/s	Avg vel of float for entire observation
1	0	Apr 17/16	SW'ly	Lt NE'ly	E'ly.	14.10 - S	4.35 - 3.72	F	20	0.80	1.38
2	0	"	"	"	"	14.10 - S	4.00 - 3.80	F	20	1.11	1.01
3	0	Apr 10/16	S'ly & NE'ly	Marked W'ly	W'ly	13.00 - S	3.90 - 4.20	R	7	2.93	1.23
4	0	"	"	"	"	13.00 - S	3.90 - 4.20	R	7	2.95	1.44
5	0	Apr 6/16	SW'ly	Lt E'ly.	S.W'ly	13.50 - S	4.5	F	18	1.70	2.48
6	0	"	"	"	"	13.50 - S	4.5	F	18	1.87	2.49
7	0	Apr 5/16	SE'ly	N.W'ly	"	13.80 - S	4.5	F	15	1.95	2.38
8	0	"	"	"	"	13.80 - S	4.5	F	15	2.00	2.46
9	0	"	S'ly	"	"	14.00 - S	4.9	S	0	2.27	2.36
10	0	"	S'ly	"	"	14.00 - S	4.85	R	5	3.00	2.96
11	0	Apr 17/16	W'ly	Lt NE'ly	E'ly	14.10 - S	4.46 - 4.50	R	4	1.22	1.21
12	0	"	"	"	"	14.10 - S	4.48 - 4.50	R	4	1.30	1.40
13	0	Apr 12/16	W'ly	N'ly	W'ly	13.20 - S	3.79 - 3.90	R	5	3.85	2.76
14	0	"	"	"	"	13.20 - S	3.75 - 3.90	R	5	3.87	2.56
7-2	0	"	SW'ly	"	W'ly.	13.35 - S	4.1	S	0	2.08	2.07
8-2	0	"	"	"	"	13.35 - S	4.1	S	0	2.12	2.48

DIRN & VEL. OF WIND DURING OBS. IS WRITTEN OPPOSITE ENCIRCLED FLOAT No



CURRENTS FOLLOW ARROW POINT.
LIGHT LINES INDICATE RISING OR STATIONARY TIDE.
HEAVY LINES INDICATE FALLING TIDE
FIGURES ALONG THE COURSE OF THE FLOAT INDICATE THE VELOCITY IN FEET PER SECOND IN THAT VICINITY.
AMOUNT OF SUBMERGENCE IS INDICATED BY ROMAN NUMERALS WRITTEN IN THE COURSE OF THE FLOAT, VIZ: X FOR 10 FT, XX FOR 20 FT ETC.

SHEET No 4
SURFACE CURRENTS.
OBSERVATIONS MADE IN APRIL, 1916.
SCALE

This chart was prepared from the hourly record of the wind direction and travel made by the local office, and by the United States Weather Bureau at Burrwood, La. The marked prevalence of Easterly winds is obvious. The resultant wind travel is from a direction slightly North of East. . . .

. . . .

When this marked prevalence of Easterly winds is considered, together with the design of the outer works and the conclusions justified by the preceding paragraphs, there is little doubt that the prevailing direction of the surface flow is to the West of the axis of the outer channel.

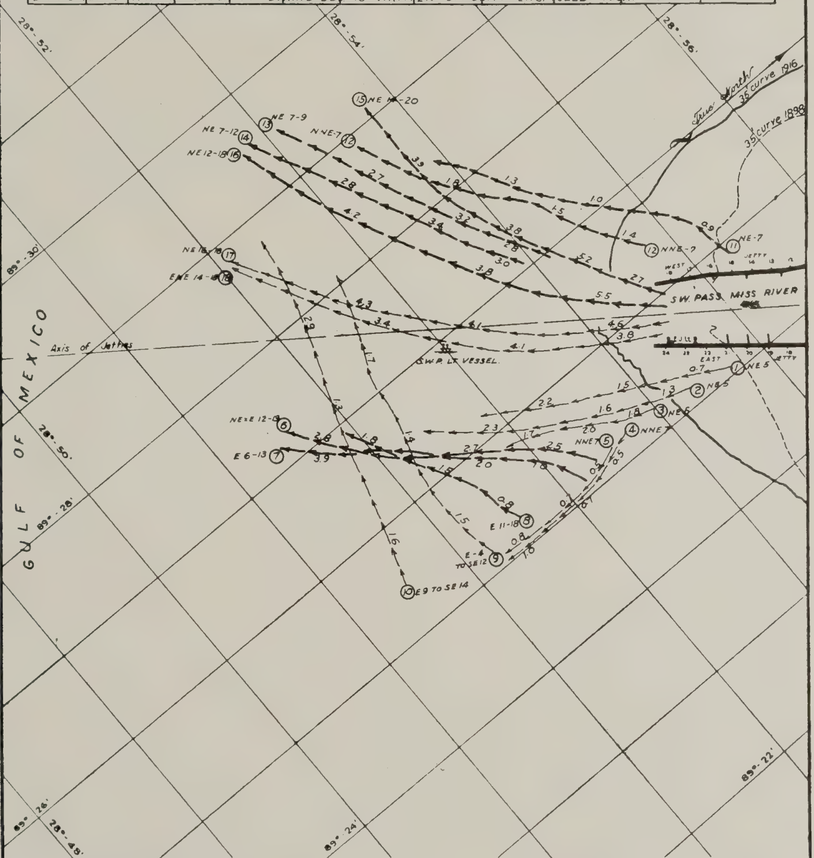
On sheets Nos. 22 and 23[1] are plotted and tabulated the results of physical analyses of 69 water samples taken on April 25, 1916, at depths of from 0 to 60 feet below the surface. The river was moderately high at the time, being 15 feet on the Carrollton gauge, and the wind, light Easterly. On sheet No. 22, vertical sections are drawn along the three lines on which the samples were taken, and the specific gravities plotted at their respective depths. From these, lines of equal specific gravities were plotted. The hatched areas represent water whose specific gravity is less than 1.01. This area very nearly represents the outflowing muddy river water, as for specific gravities greater than 1.01, there was practically no sediment in the sample. This sheet shows how the outflowing muddy river water, on leaving the jetties, spreads horizontally and passes to sea over the underlying heavier Gulf water in an ever-thinning layer. Of particular note is the fact that for equal distances seaward from the 35-foot curve, the thickness of this layer is greater in the West and Central sections than in the East section. This demonstrates that the surface flow is stronger to the West than to the East of the jetty axis.

With the results of sheet No. 22—combined with many other observations by this office, by pilots, masters of dredges, etc., from an experience extending over many years—sheet No. 24 was drawn. This is intended to show the line of demarcation between the fresh muddy river water, and the clear sea water for a moderately high river. The heavy line, bounding the hatched area, represents the boundary of the river water during a light Easterly wind, and the broken line represents the same for a similar wind from the opposite direction. This limiting line is always very clearly defined when there is any sediment in the river water, and the

[1]Sheet No. 23 not reproduced.

Float No	Am't of submergence (Ft)	Date of Obs	General Direction of travel	Prev wind for 3 days prior to Obs	Prev wind for 10 days prior to Obs.	Carrollton gauge (Ft) (R S or F)	Burrwood gauge (Ft)	Cond'n of tide R-rising, F-falling, S-Sty	Rate of change of tide in 1/100 ft per hour	Avg vel of float for 1st 6000 ft of travel in f/s	Avg vel of float for entire observation
1	0	Oct 30	SW'ly	N'ly	N.E'ly	0.40 - S	3.17 - 3.60	R	21	1.18	1.52
2	0	" "	"	"	"	0.40 - S	" "	"	21	1.43	1.72
3	0	" "	"	"	"	0.40 - S	3.40 - 3.60	"	21	1.63	1.67
4	0	" 31	S'ly.	"	"	0.45 - S	2.85 - 3.22	"	14	0.72	0.77
5	0	" "	"	"	"	0.45 - S	2.87 - 3.21	"	13	0.74	0.74
6	0	Nov. 3	SW'ly	NE'ly	"	1.45 - S	3.52 - 3.31	F	11	2.64	2.74
7	0	" 13	"	"	E'ly.	1.75 - S	3.68 - 3.40	"	14	1.23	1.75
8	0	" "	SW'ly	"	"	1.75 - S	" "	"	14	1.21	1.37
9	0	" 21	NW'ly	"	N'ly	0.90 - S	3.60 - 3.80	R	7	1.24	1.39
10	0	" 21	N.W'ly.	"	"	0.90 - S	" "	"	7	1.63	1.70
11	0	Oct 31	SW'ly	N'ly	NE'ly	1.60 - S	3.08 - 2.70	F	9	0.88	1.03
12	0	" "	"	"	"	1.60 - S	2.93 - 2.70	"	9	1.45	1.45
13	0	Nov. 3	"	NE'ly.	"	1.45 - S	3.87 - 3.74	"	13	3.00	2.80
14	0	" "	"	"	"	1.45 - S	" "	"	13	3.17	3.00
15	0	" 2	"	"	"	1.60 - S	3.30 - 3.20	"	12	4.00	4.07
16	0	" "	"	"	"	0.70 - S	3.12 - 3.00	"	10	5.05	4.14
17	0	" "	"	"	"	0.70 - S	3.05 - 3.15	R	10	4.55	4.32
18	0	" 3	"	"	"	0.90 - S.	3.26 - 3.29	R	3	3.91	3.67

DIR'N & VEL. OF WIND IN MI. PER HR. DURING OBS IS WRITTEN OPPOSITE ENCIRCLED FLOAT No



CURRENTS FOLLOW ARROW POINT.
LIGHT LINES INDICATE RISING OR STATIONARY TIDE.
HEAVY LINES INDICATE FALLING TIDE.
FIGURES ALONG THE COURSE OF THE FLOAT INDICATE THE VELOCITY IN FEET PER SECOND IN THAT VICINITY.
AMOUNT OF SUBMERGENCE IS INDICATED BY ROMAN NUMERALS WRITTEN IN THE COURSE OF THE FLOAT, VIZ X FOR 10 FT., XX FOR 20 FT ETC.

SHEET No 5
SURFACE CURRENTS.
OBSERVATIONS MADE IN OCT. & NOV., 1916
SCALE

areas represent the spread of the "fan" under the two opposite conditions of wind. During the Easterly wind, the axis of the fan bends noticeably to the Westward, while a Westerly wind only tends to flatten it out and make the "fan" more symmetrical with respect to the axis of the jetties, which is practically the same as the axis of the outflowing water, as it leaves the jetties. This is most likely due to the fact that in the former case, the wind effect is working in the same direction with the natural Westerly set given the current by the design of the works, while in the latter these influences act in opposite directions and tend to neutralize each other.

. . . .

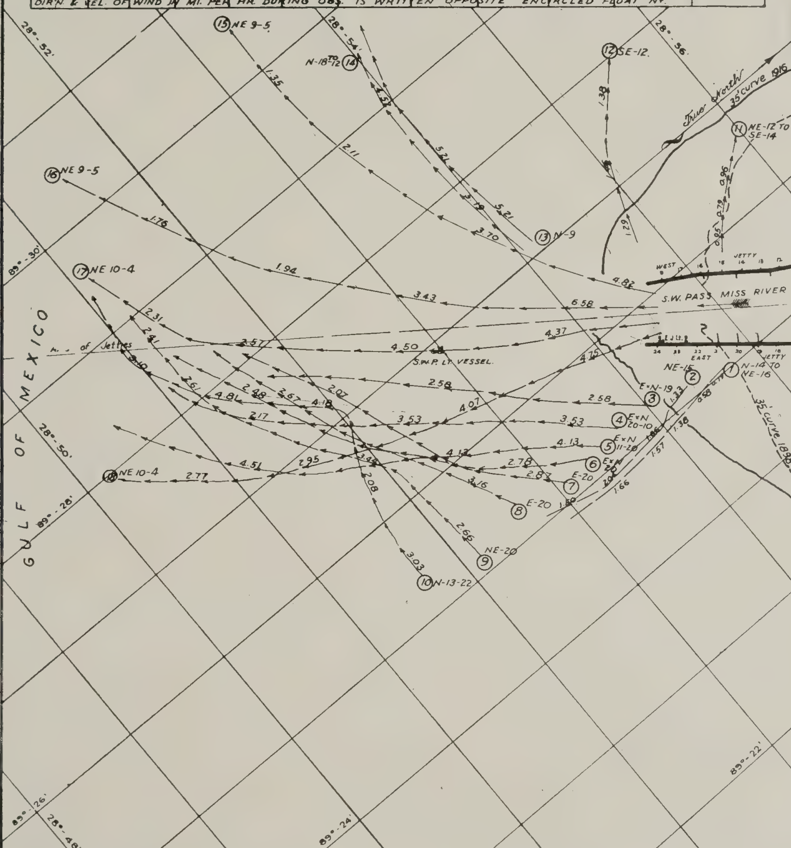
The shape of the area of river water varies greatly, being affected, as noted, by the stage of river, the wind, and the condition of the tide. During low river, which averages between 4 and 6 months of each year, the lower reach of the river is at Gulf level, and the clear sea water extends oftentimes many miles above the ends of the jetties; indeed, it is reported that on one occasion, some years back, the water supply of the City of New Orleans, 110 miles above the Gulf, and drawn from the river at this point was noticeably salty. During the low water period, the currents are comparatively feeble, being caused by the oscillation of the tide. At times during this period, the movement of the water is in an "upstream" direction, although the surface flow is usually towards the Gulf. However, since the river carries no sediment during this time, in so far as its relation to channel development is concerned, the distribution of the flow during high river is the all important consideration.

The distribution of the sediment on the sea bottom beyond and adjacent to the entrance to the Pass is undoubtedly an absolute index to the prevailing direction of flow. In this connection, however, we must remember that the river only carries sediment during its high stage, which, on the average, occurs between the months of February and July of each year. The wind charts for the fiscal year 1916-1917, and for the calendar years 1909-1917, both inclusive, have therefore been subdivided into the high and low water periods and the results shown on sheets Nos. 17 and 19. These charts show that the prevailing wind during low river is in the Northeast quadrant, and during high river in the Southeast quadrant. . . .

Before entering into the matter of this distribution of deposit,

Float No.	Am't of submergence (Ft)	Date of Obs.	General Direction of travel	Prev wind for 3 days prior to Obs.	Prev wind for 10 days prior to Obs.	Carrollton gauge (Ft) (R. S. or F)	Burrwood gauge (Ft.)	Cond'n of tide R-rising, F-falling, S-Sty	Rate of change of tide in 1/100 ft per hour	Avg vel of float for 1st 6000 ft of travel in f/s	Avg vel of float for entire observation
1	0	Feb 6/17	S'ly.	NW'ly	S'ly.	8.95 - S	3.30 - 3.56	R	11	1.02	1.21
2	0	"	"	"	S'ly	8.95 - S	3.33 - 3.56	R	11	1.63	1.60
3	0	Jan 26/17	SW'ly.	N'ly	NE'ly	9.90 - S	3.90 - 3.93	R	2	2.58	2.58
4	0	"	"	"	"	9.90 - S	3.89 - 3.93	R	2	3.53	3.23
5	0	"	"	"	"	9.90 - S	3.89 - 3.93	R	2	4.13	4.27
6	0	"	W'ly	"	"	9.90 - S	3.90	S	0	2.78	2.59
7	0	"	"	"	"	9.90 - S	3.90	S	0	2.87	2.28
8	0	"	SW'ly.	"	"	9.90 - S	3.90	S	0	3.00	2.77
9	0	"	"	"	"	9.80 - S	3.04 - 4.18	R	57	2.66	2.91
10	0	"	W'ly.	"	"	9.90 - S	3.96 - 4.13	R	8	2.71	3.28
11	0	Feb 6/17	NW'ly.	NW'ly	S'ly	9.05 - S	3.60 - 3.75	R	7	0.91	0.91
12	0	"	"	"	"	9.05 - S	3.74 - 3.90	R	8	1.42	1.40
13	0	Jan 26/17	W'ly	N'ly	NE'ly	9.80 - S	4.18	S	0	5.21	4.73
14	0	"	"	"	"	9.80 - S	4.19	S	0	5.19	4.78
15	0	Feb 3/17	"	NW'ly	SE'ly.	8.40 - S	3.86 - 4.18	R	9	4.82	2.56
16	0	"	SW'ly.	"	"	8.40 - S	3.80 - 4.14	R	9	6.58	2.83
17	0	"	"	"	"	8.40 - S	3.80 - 4.14	R	9	4.37	3.18
18	0	"	"	"	"	8.40 - S	3.80 - 4.14	R.	9	4.75	3.44

DIR'N. & VEL. OF WIND IN MI. PER HR. DURING OBS. IS WRITTEN OPPOSITE ENCIRCLED FLOAT No.



CURRENTS FOLLOW ARROW POINT.
LIGHT LINES INDICATE RISING OR STATIONARY TIDE.
HEAVY LINES INDICATE FALLING TIDE
FIGURES ALONG THE COURSE OF THE FLOAT INDICATE THE VELOCITY IN FEET PER SECOND IN THAT VICINITY.
AMOUNT OF SUBMERGENCE IS INDICATED BY ROMAN NUMERALS WRITTEN IN THE COURSE OF THE FLOAT, VIZ: X FOR 10 FT, XX FOR 20 FT ETC.

SHEET No 6
SURFACE CURRENTS.
OBSERVATIONS MADE IN JAN. & FEB., 1917.
SCALE

certain principles, conditions, and other considerations bearing on the matter should be recalled. The amount of sediment that passes the ends of the Southwest Pass jetties is of course variable; a range of figures is given by different investigators for the lower Mississippi, to which those for the Pass are proportionate, but it is easily computed from data at hand to average over 100,000,000 cubic yards per annum. On sheet No. 46, which was carefully prepared from complete surveys, the amount of deposit in an area of two square miles directly beyond the jetty ends, between March, 1898, and June, 1909, was 61,949,000 cubic yards, and in the same area, for the period June, 1909, to June, 1915, 25,594,000 cubic yards, or an average of about 5,000,000 cubic yards per annum for the entire period from March, 1898, to June, 1915. This is only about 5 per cent of the sediment that passed the jetty ends, and the area under consideration extends between 3,000 and 6,000 feet beyond the respective positions of the 35-foot curve, or 2,000 feet farther, from the ends of the jetties. It is most obvious from this that by far the majority of the river sediment is carried and deposited a considerable distance to sea.

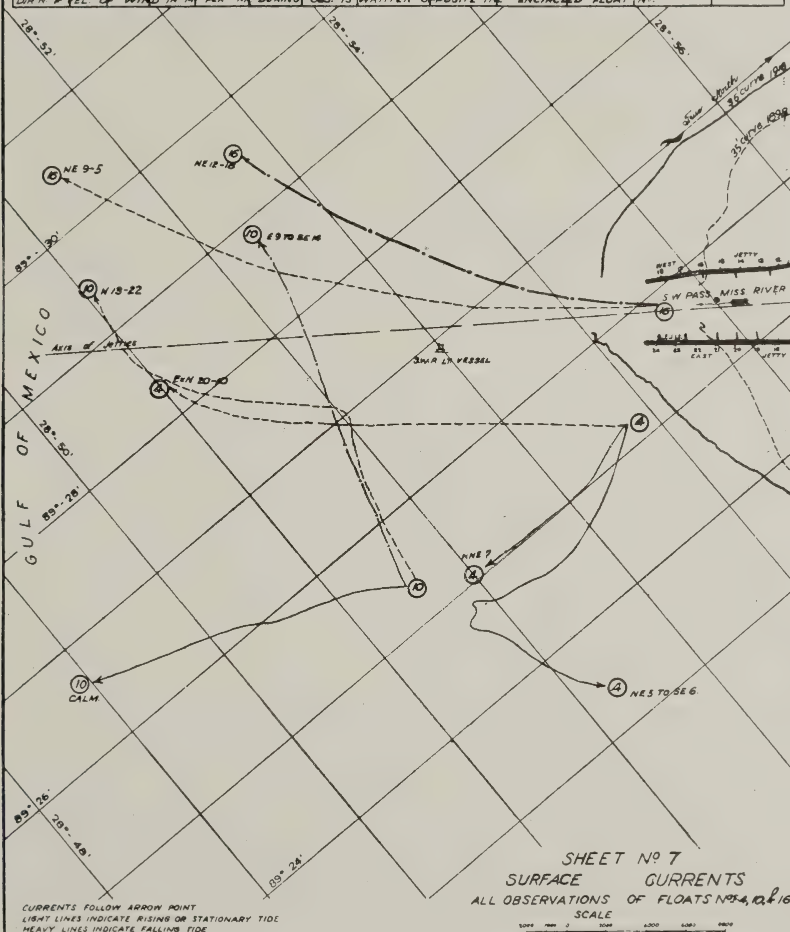
The river water transports sediment in two ways; the finer and lighter particles are carried in suspension, and the larger and heavier ones are rolled along the bottom. This latter is variously estimated at from 2 to 10 per cent of the total load. The greater part of and the heavier and coarser material in suspension is carried in the lower layers of water, since the more rapidly decreasing velocities in a vertical section cause a greater upward pressure.

During very high river, the jetty confinement gives the river water sufficient momentum to completely displace the sea water to a distance of about 3,000 feet seaward from the jetty ends. The river water then passes over the heavier underlying Gulf water and gradually thins out to nothing at a distance of probably about 10 miles from the same point. Before the construction of jetties, due to the lesser energy of outflow, under the same condition of stage of river, the ability of the river to displace the sea water was much less, and its thickness for given distances seaward much smaller. During lower stages of the river, this condition is modified accordingly, until during low river the sea water, even to the surface, extends a considerable distance upstream from the jetty ends.

. . . .

Float Nº	Symbol	Amt of Submergence (Ft)	Date of Obs	General Direction of travel	Prev. wind for 3 days prior to obs	Prev. wind for 10 days prior to Obs.	Carrollton gauge (Ft) (R, S, or F)	Burrwood gauge (Ft)	Cond'n of tide R-rising, F-falling, S-St'y.	Rate of change of tide in 1/100 ft. per hour	Avg. vel. of float for 1st 6000 ft of travel in f/s	Avg. vel. of float for entire observation
4	——	0	Apr. 10/16	S'ly & NE'ly	Mixed [illegible]	W'ly	13.00 - S	3.90-4.20	R	7	2.95	1.44
4	— · — —	0	Oct. 31/16	S'ly	N'ly	NE'ly	8.[illegible] - S	2.85-3.22	R	14	0.72	0.77
4	- - - - -	0	Jan. 26/17	SW'ly	"	"	[illegible] - S	3.89-3.93	R	[illegible]	3.53	[illegible]
10	——	0	Apr. 5/16	S'ly	NW'ly	SW'ly	14.00 - S	4.85	R	5	3.00	[illegible]
10	— - —	0	Nov. 21/16	NW'ly	NE'ly	N'ly	8.90 - S	3.60-3.80	R	7	1.63	1.70
10	- - - -	0	Jan. 26/17	W'ly	N'ly	NE'ly	[illegible] - S	3.96-4.13	R	8	2.71	[illegible]
16	— · — · —	0	Nov. 2/16	SW'ly	NE'ly	NE'ly	8.70 - S	3.72-3.00	F	10	3.05	4.14
16	- - - -	0	Feb. 3/16	SW'ly	NW'ly	SE'ly	8.40 - S	3.80-4.14	R	9	4.37	3.18

DIR'N & VEL. OF WIND IN MI PER HR DURING OBS. IS WRITTEN OPPOSITE THE ENCIRCLED FLOAT Nº.



SHEET Nº 7
SURFACE CURRENTS
ALL OBSERVATIONS OF FLOATS Nºs 4, 10, & 16

The distribution of the sediment and the advance of curves in the areas to seaward from the jetty ends, is an indication of the prevailing direction of both the surface and sub-surface currents. . . .

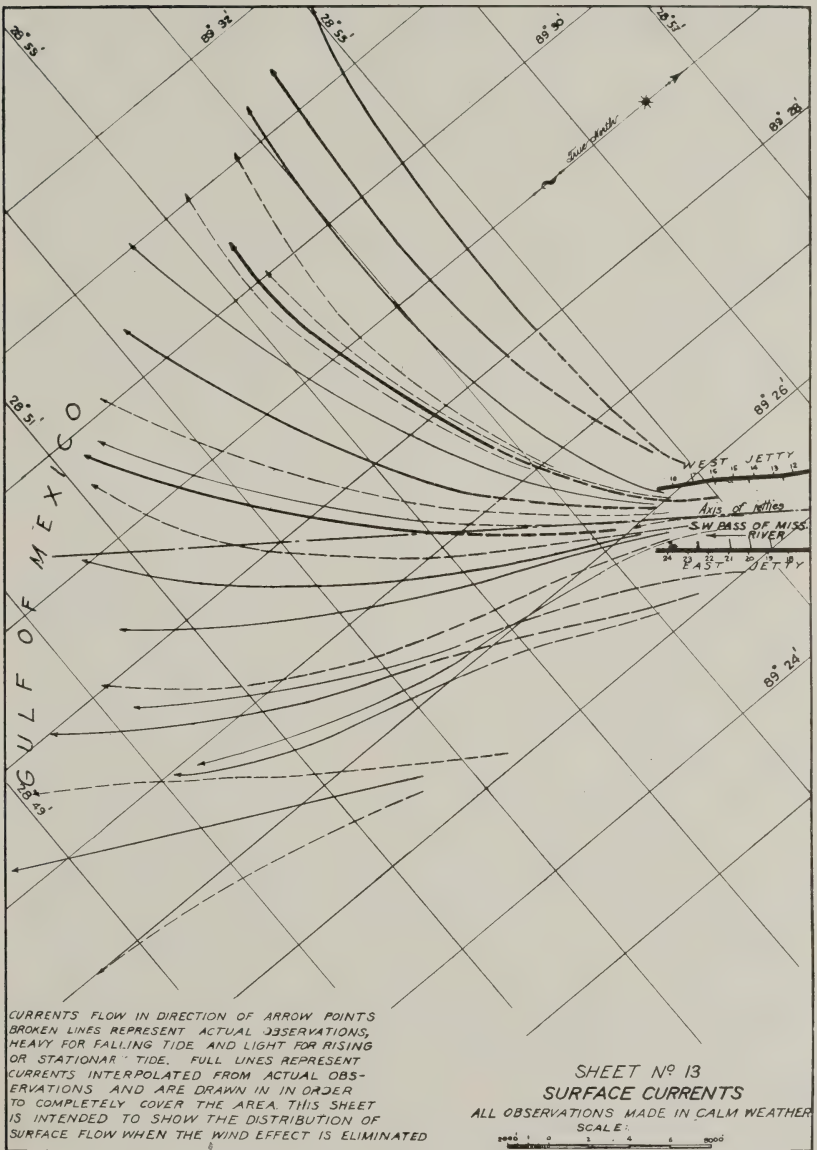
As a general rule, the sub-surface flow in the Gulf is very weak compared with the surface flow, as will be evident from the consideration of sub-surface currents later. . . .

. . . .

. . . west of the axis of the lower end of the Pass for different periods between the years 1839 and 1916. This chart shows that the average advance in the west sector during any of the periods, was greater than in the east; that the advance near the western portion of the west sector was always much greater than the advance in the east sector an equal distance east of the channel axis. This shows, without doubt, that the prevalence of flow was to the west of the channel axis; the greater part of the sediment causing this advance was probably carried over by the upper layers of water. The graph on this sheet gives the comparative advance of the 35-foot curve in the east and west sectors; it shows how this curve in the west sector is gradually pushing faster to seaward than in the east sector.

A glance at sheet No. 1, showing the lower reach of the river from Point A La Hache to the Gulf, shows that the thickness of the bank of land on the west side of the river is always much greater than that on the east, although full account must be taken in making this comparison of the prevalence of outlets. These were nearly always of about equal extent on each side of the river. This again, in a general way, indicates a prevalence of flow to the westward during the long period that the river was building up and extending its banks.

Sheet No. 21 shows the average advance of the 35-foot curves and the deposit between them in equal sectors to the east and west of the channel axis, in the period from 1867 to 1905. The average advance, the area of deposit between the curves, and the total deposit, is considerably greater in the west than in the east sector. The average depth of deposit, however, is greater in the east sector. This latter, although at first glance appearing to disprove the prevalence of westerly current, in reality is a strong proof when we remember that a prevailing and stronger westerly current would carry the materials farther and spread them over a much greater area to the westward, and the materials carried to


28° 59'
89° 32'
28° 55'
89° 30'
28° 53'
89° 28'
True North
89° 26'
28° 51'
GULF OF MEXICO
WEST JETTY
Axis of jetties
S.W. PASS OF MISS. RIVER
EAST JETTY
89° 24'
28° 49'
CURRENTS FLOW IN DIRECTION OF ARROW POINTS
BROKEN LINES REPRESENT ACTUAL OBSERVATIONS,
HEAVY FOR FALLING TIDE AND LIGHT FOR RISING
OR STATIONARY TIDE. FULL LINES REPRESENT
CURRENTS INTERPOLATED FROM ACTUAL OBS-
ERVATIONS AND ARE DRAWN IN IN ORDER
TO COMPLETELY COVER THE AREA. THIS SHEET
IS INTENDED TO SHOW THE DISTRIBUTION OF
SURFACE FLOW WHEN THE WIND EFFECT IS ELIMINATED
SHEET No. 13
SURFACE CURRENTS
ALL OBSERVATIONS MADE IN CALM WEATHER
SCALE:

the eastward would be spread over a smaller area, and closer to the jetty axis, due to the weaker current, giving a greater depth of deposit in a given area than for a similarly placed area on the west side. The comparative advance of the 35-foot curves, area, average depth of and amount of deposit between them, verify absolutely that the prevailing surface flow, governed by the prevailing easterly winds, is to the westward of the axis of the outer channel.

. . . .

From the foregoing, the distribution of surface flow, etc., in the Gulf beyond the jetty ends, may be summarized as follows:

(1) The surface flow, on passing the ends of the jetties, spreads out, or tends to spread out, in fan-like shape, gradually losing the velocity imparted to it by the jetty confinement as it passes to sea.

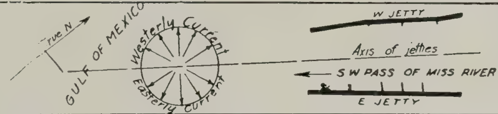
(2) As the different filaments of flow comprising this fan gradually lose the velocity due to jetty confinement, their direction gradually conforms to that of the wind, and their velocity to the wind intensity.

(3) The direction and velocity of surface flow at any point seaward from the jetty ends, is the resultant of the combined influences of the energy and direction of outflow due to jetty confinement and of the direction and intensity of the wind.

(4) The shape of the fan is therefore governed by the stage of the river, the direction and intensity of the wind, and the condition of the tide.

(5) During calm weather the axis of the fan bends perceptibly to the westward of the jetty axis, due to the design of the outer works. This bend of the axis of the fan to the westward increases with the strength of an easterly wind, while a westerly wind only tends to flatten it out to the eastward. Only under very exceptional conditions does the axis of the fan bend to the east of the jetty axis. The fan extends further seaward and its axis bends more to the westward as the stage of river and the rate of fall of the tide increases. A Northerly wind lengthens the axis of the fan.

(6) During medium or high river, the surface flow is comprised of the muddy river water which passes to sea over the underlying heavier Gulf water in an ever thinning layer. Where the thickness of this layer is zero, the line of demarcation between



In interpreting the relation between the dir'n. of the wind during the obs'n. and that of the current, some allowance was made for the natural spread of the river water as it leaves the jetties

SURFACE CURRENTS

Observation Nº	Date of Observation	Direction of wind during observation	Direction of current	Direction of current plainly in accord with direction of wind during Obs	Direction of current partially or doubtfully in accord with dir'n. of wind during Obs	Direction of current apparently uninfluenced by wind during observation	Gen'l dir'n of current (See sketch above) Easterly	Westerly
5-a	Apr. 27/15	Fresh S E	S'westerly	/				/
4-b	" 28/15	Lt. N.W	"		/			/
8-b	" " "	"	"		/			/
1-c *	May 1/15	"	Southerly	/			/	
3-c *	" " "	"	S'westerly		/		/	
1-f	" 10/15	Mod. S.E	"	/				/
1	Apr. 17/16	E – 7mi	"	/				/
1	Oct. 30/16	N.E – 5mi.	"	/				/
1	Feb. 6/17	N – 14 mi	Southerly	/			/	
2	Apr 17/16	E – 7 mi	S'westerly	/				/
2	Oct 30/16	N E – 5 mi.	"	/				/
2	Feb. 6/17	N E – 15 mi	Southerly		/		/	
3	Apr. 10/16	Lt NE to SE	S'ly & NE'ly	/			/	
3	Oct. 30/16	NE – 5mi	S'westerly	/			/	
3	Jan. 26/17	ExN – 19 mi	"	/				/
4	Apr 10/16	Lt NE to SE	S'ly & NE'ly	/			/	
4	Oct. 31/16	NNE 7mi.	Southerly	/			/	
4	Jan. 26/17	ExN 20 to 10mi	S'westerly	/				/
5	Apr. 6/16	ESE 8 mi	"	/				/
5	Oct. 31/16	NNE 7mi.	Southerly	/			/	
5	Jan. 26/17	ExN-11 to 20mi	S'westerly	/				/
6	Apr. 6/16	ESE 8mi	S'westerly	/				/
6	Nov 3/16	NExE-12 to 19mi	"	/				/
6	Jan 26/17	ExN 21 to 18mi	Westerly	/				/
7	Apr. 5/16	N.W. 6 mi.	S'easterly	/			/	
7-2	Apr 12/16	E 7mi.	S'westerly	/				/
7	Nov. 13/16	Lt. NE to E.	"	/				/
7	Jan 26/17	E to ExN 20 mi	Westerly	/				/
8	Apr 5/16	N.W. 6 mi.	S'easterly	/			/	
8-2	Apr. 12/16	E – 7mi	S'westerly	/				/
8	Nov 13/16	E-11 to 18mi.	"	/				/
8	Jan 26/17	E- 20mi.	"	/				/
9 †	Apr. 5/16	Calm	Southerly		/		/	
9	Nov. 21/16	ExN to SE 10mi	N'westerly	/				/
9	Jan 26/17	NE 20 mi.	S'westerly	/				/
10 †	Apr 5/16	Calm	Southerly	/			/	
10	Nov. 21/16	E to SE 12mi	N'westerly	/				/
10	Jan 26/17	N 13 to 22 mi.	Westerly		/			/
11 †	Apr. 17/16	NW 2mi	"		/			/
11	Oct 31/16	NE 7mi.	S'westerly	/				/
11	Feb. 6/17	NE to SE 13mi.	N'westerly	/				/
12 †	Apr. 17/16	NW 2 mi.	Westerly		/			/
12	Oct. 31/16	NE 7mi.	S'westerly	/				/
12	Feb. 6/17	SE 12 mi.	N'westerly	/				/
13	Apr. 12/16	E 3mi	Westerly	/				/
13	Nov. 3/16	NE 8mi	S'westerly	/				/
13	Jan. 26/17	N 7 to 11mi	Westerly		/			/
14	Apr 12/16	E 3mi.	"	/				/
14	Nov. 3/16	NE-7 to 12 mi	S'westerly	/				/
14	Jan 26/17	N 18 to 12 mi	Westerly		/			/
15	Nov. 2/16	NE 14 to 20mi	S'westerly	/				/
15	Feb. 3/17	NE 9 to 5 mi.	Westerly	/				/
16	Nov. 2/16	NE 12 to 18mi	S'westerly	/				/
16	Feb. 3/17	NE 9 to 5mi.	"	/				/
17	Nov. 2/16	NE 16 to 18 mi	"	/				/
17	Feb. 3/17	NE 10 to 4mi.	"	/				/
18	Nov 3/16	ENE 14 to 18mi.	"	/				/
18	Feb. 3/17	NE 10 to 4mi.	"	/				/
TOTALS				46	6	0	9	43
% OF TOTAL Nº OF OBSERVATIONS				88.4	11.6	0.0	17.3	82.7

* Not included in totals as these floats were mainly under the influence of the river current
† " " " " as there was very little wind during Observation.

Easterly or Westerly current as noted in the last 2 columns refers to a direction to the east or west of the jetty axis & on a/c of the direction of this axis will not always be in the true E or W semi-circle, but as indicated in sketch above.

SHEET Nº 14
SURFACE CURRENTS
TABULATION OF RESULTS.

the muddy water of the river and the clear water of the Gulf is very plain, there being very little comingling of the two waters.

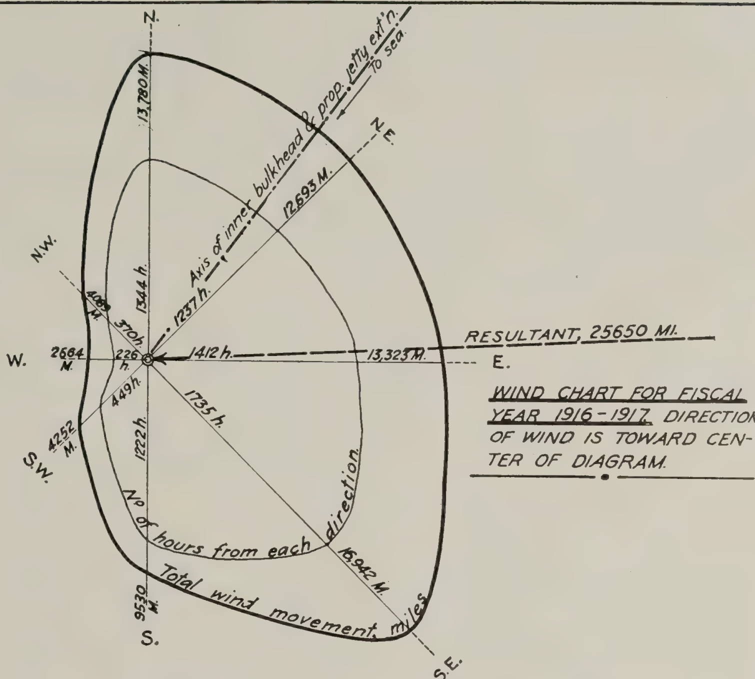
(7) During low river the Gulf water extends well up the Pass and into the main river. At this time the outflow at the ends of the jetties is due entirely to the fall of the tide. The currents, on the average, are then comparatively feeble and the spread of the fan more restricted than during high river. At times during this period, when the weather is calm, the current runs up into the ends of the jetties. The currents further seaward are affected then to a greater degree and usually entirely by the wind.

(8) The velocity of flow is a function of, and increases with the proximity to the face of the jetties, direction and intensity of wind, and stage of river, these influences being strongest in the order named. The velocity of flow is also affected by the condition of the tide, increasing with the rapidity of a falling tide and decreasing with the rapidity of a rising tide. The tidal influence during the high stages of the river is very small.

(9) Other things being equal, within the effective area of outflow due to jetty confinement, for equal distances seaward from the ends of the jetties, the velocity is greater to the west of the axis of the jetties than at the same distance to the eastward. The greatest velocity is usually found on the axis of outflow, which is approximately the axis of the jetties, at a point abreast of or immediately beyond the jetty ends.

(10) The prevailing surface flow, caused by the prevailing easterly wind and the design of the outer works, is decidedly to the westward of the jetty axis; the resultant of this flow within the area in front of the jetties crosses the axis of the jetties, making an angle of probably about 45° on the lower west side of this axis. Since during the high stage, when the river is carrying sediment, the prevailing wind is from a direction nearly Southeast, the surface flow during this time tends to sweep directly across the face of the jetties, but, due to the energy of the outflowing water, caused by jetty confinement, is modified, so that the resultant prevailing flow probably makes an angle of about 60° with the axis of the jetties, measured on the lower west side of this axis. Further seaward, beyond the influence of outflow, the prevailing surface current, during high river, is parallel to the face of the jetties.

The cause and the distribution of the sub-surface flow pre-



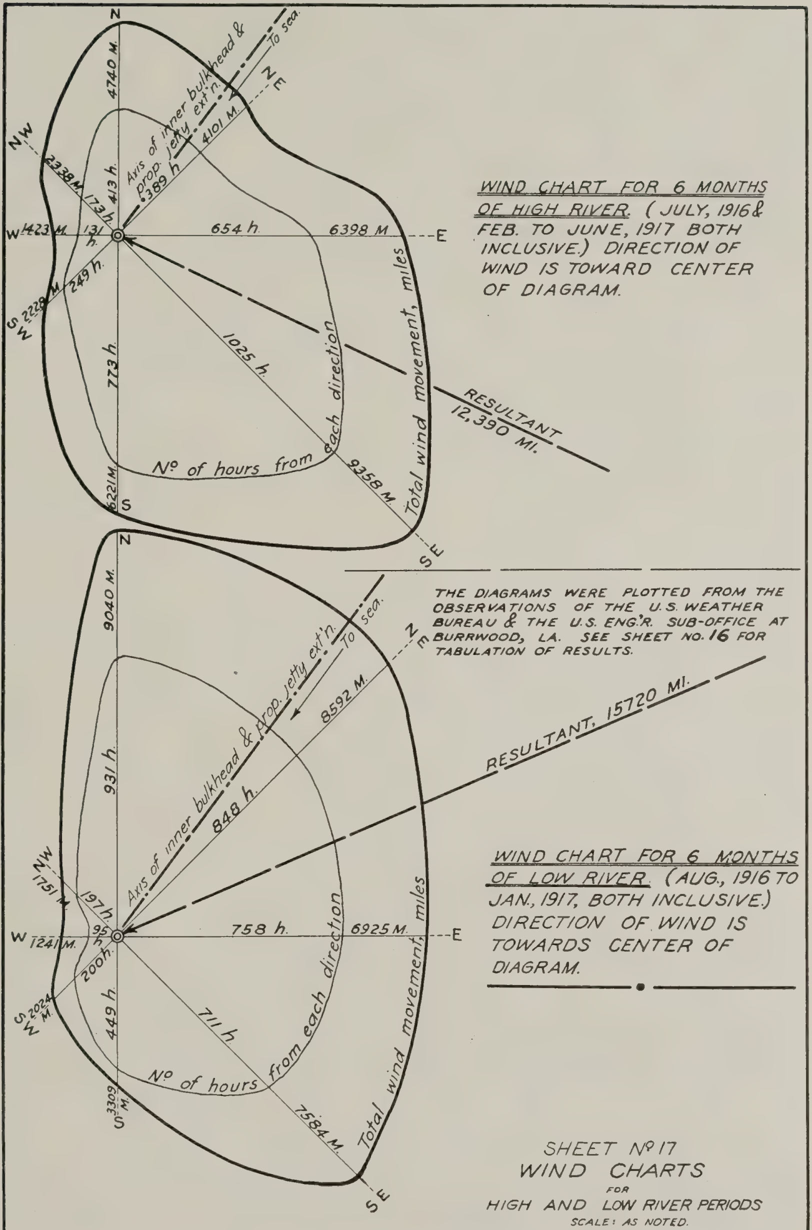
BURRWOOD, LA.–FISCAL YEAR 1917

	MONTH	TOTAL WIND TRAVEL, MILES: N	NE	E	SE	S	SW	W	NW	NO. OF HOURS FROM EACH DIR'N.: N	NE	E	SE	S	SW	W	NW.
HIGH RIVER PERIOD	Feb. 1917	1489	350	520	1399	1314	195	329	810	100	32	63	171	164	19	29	61
	Mar., "	1103	1029	978	2462	1195	84	23	521	84	96	95	282	138	10	4	29
	Apr., "	884	610	1836	1683	648	185	566	868	93	62	177	159	88	28	36	61
	May, "	867	1496	1087	1847	1489	361	126	73	90	127	97	170	152	48	20	11
	June, "	377	438	520	1781	1119	522	117	66	41	50	99	214	162	69	21	11
	July, 1916	20	178	1457	186	456	881	262	0	5	22	123	29	69	75	21	0
	TOTALS	4740	4101	6398	9358	6221	2228	1423	2338	413	389	654	1025	773	249	131	173
LOW RIVER PERIOD	Aug., 1916	290	351	1658	1404	939	838	84	127	46	62	200	165	142	67	15	26
	Sept., "	888	1685	1478	1116	438	143	126	80	102	168	188	137	62	15	18	14
	Oct., "	2221	2055	1928	608	0	511	258	258	223	236	161	51	0	33	12	21
	Nov., "	2516	1440	1309	1268	214	51	465	273	223	165	129	98	13	11	26	28
	Dec., "	1632	973	282	1581	591	230	90	395	157	122	50	132	76	23	6	54
	Jan., 1917	1493	2088	270	1607	1127	451	218	618	180	95	30	128	156	51	18	54
	TOTALS	9040	8592	6925	7584	3309	2024	1241	1751	931	848	758	711	449	200	95	197
TOTAL FOR FISCL. YR. 1917		13,780	12,693	13,323	16,942	9,530	4,252	2,664	4,089	1344	1237	1412	1736	1222	449	226	370

THE DIAGRAMS WERE PLOTTED FROM THE OBSERVATIONS OF THE U.S. WEATHER BUREAU AND THE U.S. ENG.'R. SUB-OFFICE AT BURRWOOD, LA.

SHEET Nº 16
WIND CHART
FOR
FISCAL YEAR 1917
SCALE AS NOTED

sents a more complex problem than for the surface currents. Masters of vessels, pilots, and others of long experience on the waters near the mouth of the Passes claim that there exists a westerly current along and near the Gulf coast in the path usually traversed by coastwise vessels. Based on the observations of masters of such vessels, the United States Hydrographic Office, on its chart of the Gulf currents, copy of which is presented on sheet No. 47, shows this current extending along and just inside of 100-fathom curve. This current is claimed to be a continuation of the Labrador current extending in a Southerly direction along the Atlantic coast, passing close to shore around the Florida Peninsula, where it is known as the Florida countercurrent, thence westward inside the 100-fathom curve in the Gulf, where it goes by the name of the western countercurrent. The 100-fathom curve passes about 30 miles seaward from the ends of the Southern Pass jetties; the proximity of the influence of this current to the ends of the jetties appears not to be definitely known or stated; the observations on which this report is based seldom extended further than about 6 miles from the ends of the jetties, and certainly they show that there is, at least at times, an easterly movement of the sub-surface water at this distance seaward, which is about 60 miles from the general mainland. At any rate, since the existence of this westerly current is based on the drift of vessels, the latter would indicate more a movement of the upper 20 or 30 foot stratum of water, of which the surface current, as has been shown, has a strong prevailing westerly set, due to the marked prevalence of easterly winds which give the surface water its movement. The thickness of the surface layer of water which moves directly with the winds, is shown by many obesrvations not to exceed about 10 feet. Below this depth the observations show that very seldom is the direction of the current the same as that of the wind during the observation. Whatever the exact proximity to shore of the western countercurrent shown on current charts of the Gulf, or whatever its cause, it is probable that the currents in the area immediately beyond the ends of the jetties, the currents which have a direct bearing on the distribution of the sediment and of channel development, are influenced by more local considerations. These are the currents covered by this report and by the observations; they are included in an area between the ends of the jetties and a line about 6 miles seaward therefrom.


WIND CHART FOR 6 MONTHS OF HIGH RIVER. (JULY, 1916 & FEB. TO JUNE, 1917 BOTH INCLUSIVE.) DIRECTION OF WIND IS TOWARD CENTER OF DIAGRAM.
Axis of inner bulkhead & prop. jetty ext'n.
To sea.
RESULTANT 12,390 MI.
Total wind movement, miles
No. of hours from each direction
THE DIAGRAMS WERE PLOTTED FROM THE OBSERVATIONS OF THE U.S. WEATHER BUREAU & THE U.S. ENG'R. SUB-OFFICE AT BURRWOOD, LA. SEE SHEET NO. 16 FOR TABULATION OF RESULTS.
RESULTANT, 15720 MI.
WIND CHART FOR 6 MONTHS OF LOW RIVER. (AUG., 1916 TO JAN., 1917, BOTH INCLUSIVE.) DIRECTION OF WIND IS TOWARDS CENTER OF DIAGRAM.
SHEET No. 17
WIND CHARTS
FOR
HIGH AND LOW RIVER PERIODS
SCALE: AS NOTED.

On sheets Nos. 25 to 34, inclusive[1], are shown the paths of all sub-surface currents observed, each sheet containing one set of observations made in the period noted. Sheet No. 35 shows the drift of the tug *C. Donovan* and of the dredge *New Orleans,* indicating the movement of the upper 10 and 20 foot strata of water in accordance with the draft of these vessels. On sheets Nos. 36 to 43, inclusive[2], the same observations are grouped from the same starting points. Tabulated data that it was thought might bear on the cause of these currents is given on all of the sheets.

These observations show, even at first glance, that the under layers of water do not move uniformly in any direction; that the flow is sometimes to the east, and sometimes to the west of the axis of the jetties; and that the sub-surface flow is not generally in the same direction as the surface current. This latter is evident from the observations plotted on sheet No. 29, where both the surface and sub-surface currents were observed at the same time, there being an angle of nearly 90 degrees between their directions. During a great many of the observations, it was noticeable that the surface float was being towed by the under current through the surface current, oftentimes nearly opposite in direction to the latter.

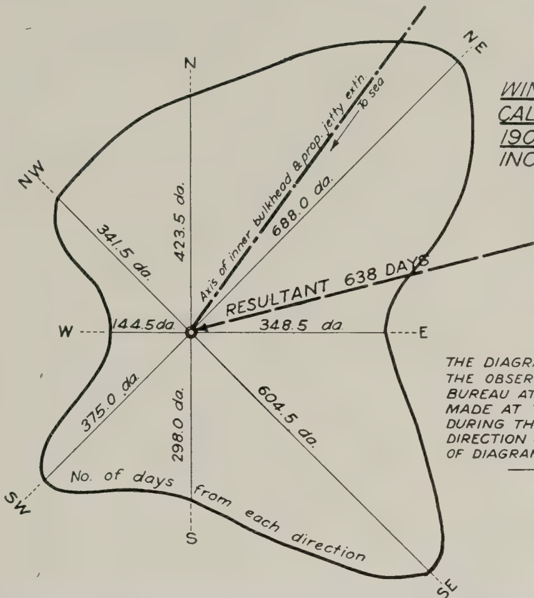
In studying the sub-surface currents, it must be noted whether the under float was traveling in the outflowing river water, or in the underlying Gulf water. In making this estimate, due consideration must be given to the stage of river, tide, and intensity and direction of the wind, all of which factors affect the ability of the river water to displace the water in the Gulf.

Floats Nos. 6, 7, 8, 9, and 10, on account of their depth of submergence and distance from the jetty ends, in all of the observations, traveled entirely in the underlying sea water. For the remaining floats, during the higher stages of the river, a small part of their initial travel was in the river water and the remaining part in the Gulf water.

Where the floats were traveling in the river water, or during low river, near the jetty ends, their travel was influenced to a large extent by the natural spread due to jetty confinement, indicating that the sub-surface current, although with smaller velocities, parallels the surface current within the area of this influence

[1]Sheet No. 27 not reproduced.

[2]Not reproduced.



WIND CHART FOR CALENDAR YEARS 1909 TO 1917-(BOTH INCLUSIVE)

THE DIAGRAM WAS PLOTTED FROM THE OBSERVATIONS OF THE U.S. WEATHER BUREAU AT BURRWOOD, LA. WHICH WERE MADE AT 7:00 A.M. & 7:00 P.M. DAILY DURING THIS PERIOD.
DIRECTION OF WIND IS TOWARDS CENTER OF DIAGRAM.

BURRWOOD, LA, CALENDAR YEARS 1909 TO 1917 INCL.

NUMBER OF DAYS WIND BLEW FROM EACH DIRECTION.

Period	YEAR	N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.
HIGH RIVER PERIOD — FEB. TO JULY BOTH INCLUSIVE.	1909	15.5	20.0	18.0	56.5	20.0	29.0	12.0	9.5
	1910	11.5	21.0	11.0	39.5	19.0	39.0	11.5	24.5
	1911	2.0	34.5	14.5	59.5	12.5	35.0	10.0	12.5
	1912	8.5	43.5	10.5	52.5	13.0	29.0	8.0	16.0
	1913	10.5	48.0	11.0	31.5	20.0	28.0	3.5	28.0
	1914	8.0	33.0	26.5	33.0	10.0	27.5	8.5	31.5
	1915	31.5	21.0	35.0	15.5	29.5	22.0	9.0	15.0
	1916	36.5	23.5	22.0	13.5	43.0	18.5	7.5	3.5
	1917	17.0	23.0	16.5	40.5	39.5	23.0	6.5	9.0
	TOTALS	141.0	267.5	165.0	342.0	206.5	251.0	76.5	149.5
LOW RIVER PERIOD — JAN., AND AUG. TO DEC., BOTH INCL.	1909	39.0	38.5	27.5	31.0	11.0	10.5	10.5	15.0
	1910	19.5	52.5	14.5	36.5	9.5	21.0	7.0	23.0
	1911	18.0	45.0	11.0	47.5	7.5	19.5	8.0	24.5
	1912	17.5	58.0	7.0	37.5	8.5	14.0	2.0	37.5
	1913	17.5	53.0	16.0	34.5	12.0	9.5	9.5	25.0
	1914	32.0	47.5	22.0	19.5	2.0	17.0	6.5	31.0
	1915	38.0	49.0	29.5	20.5	9.0	17.5	8.0	9.0
	1916	57.0	36.0	35.5	18.0	15.5	3.5	5.0	8.5
	1917	44.0	41.0	20.5	17.5	16.5	11.5	11.5	18.5
	TOTALS	282.5	420.5	183.5	262.5	91.5	124.0	68.0	192.0
TOTAL FOR CAL. YEARS 1909-1917 BOTH INCL.		423.5	688.0	348.5	604.5	298.0	375.0	144.5	341.5

SHEET № 18
WIND CHART
CALENDAR YEARS 1909 TO 1917.
BOTH INCLUSIVE
SCALE: AS NOTED

or that the spread of the "fan" extends through the thickness of the layer of river water as it leaves the jetties. Outside of the influence of the outflowing river water the direction of the sub-surface flow is variable, but in the majority of the observations (63.4 per cent), the set was to the East of the axis of the jetties. . . .

The direction of these currents shows generally no relation to the direction of the wind during the observation. . . .

Referring to sheet No. 1, it is plain that the land on the west side of the river has been built up to greater width than on the east; referring again to sheets Nos. 20 and 21, and to sheets Nos. 45 and 46, which will be studied in further detail later, it is obvious that the greater part of the river sediment is carried to the west of the axis of the lower end of the Pass; pilots, masters of dredges, etc., claim that the currents, to a depth equal to the usual draft of vessels, are generally to the westward, although at times to the east.

Giving due weight to all of these factors, especially the distribution of sediment, it is most logical to suspect that the prevailing underflow is to the westward of the axis of the jetties.

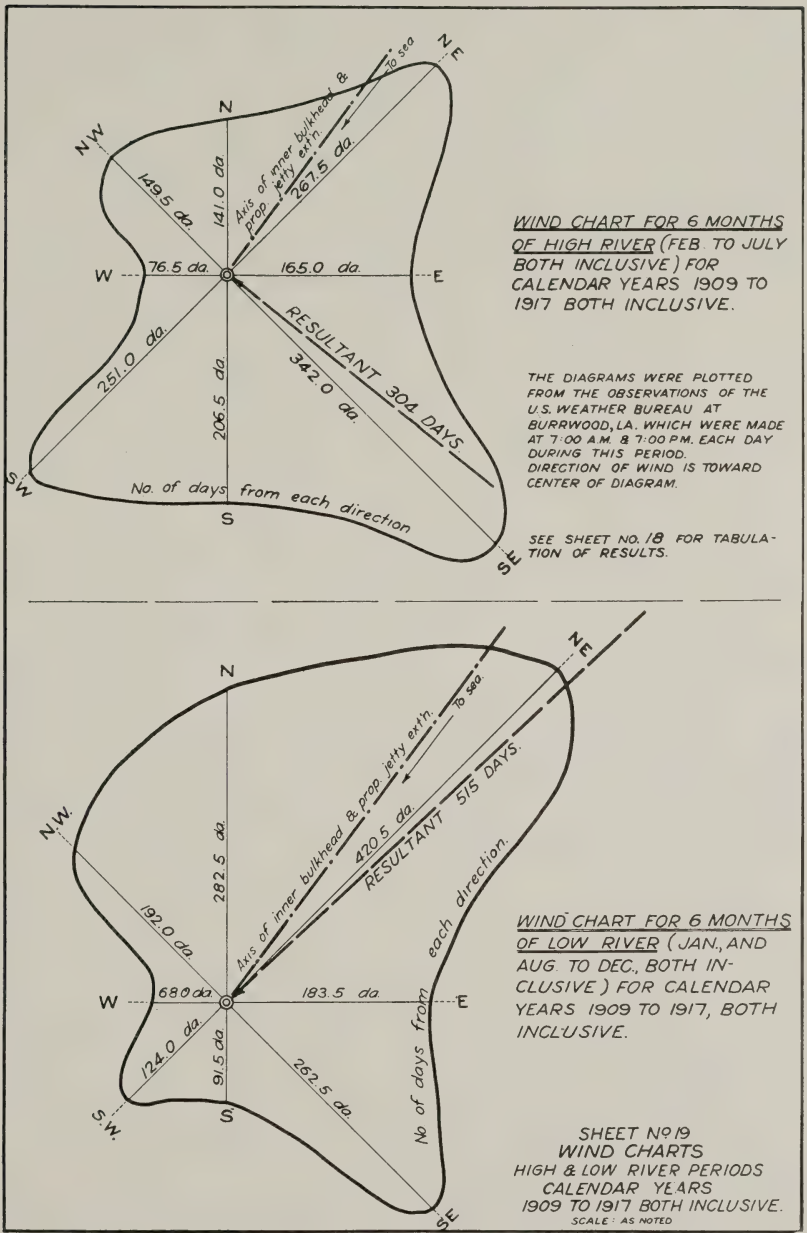
. . . .

. . . In general, however, it is believed that on the average the prevailing wind for about three days immediately prior to the observation should control the directions of currents, if effected, as we have good reasons to believe by the difference in elevation between the water surfaces, caused by the banking up of the water by these winds.

. . . .

With such a marked prevalence of Easterly winds, considering the matter of the preceding paragraphs, there is little doubt that the prevailing flow of the sub-surface water is generally in a direction to the West of the axis of the jetties, or has been, before the jetties were constructed, in a direction to the West of the axis of the lower end of the Pass.

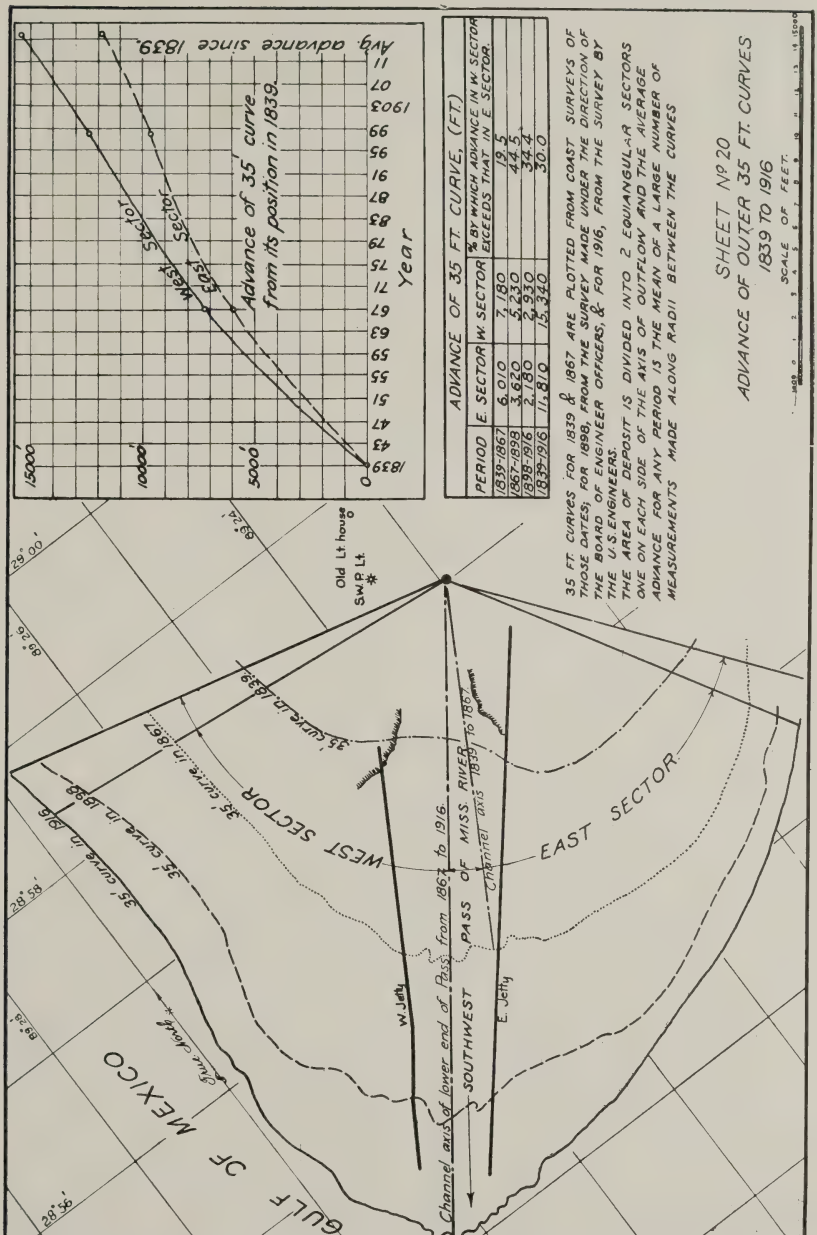
Sheet No. 48 was prepared to show the most probable cause and distribution of the sub-surface flow, in accordance with the foregoing, for the high water period. This latter period is taken for the reason that the river carried sediment only during its high stage, and the currents affecting the distribution of this sediment are the ones we are mostly interested in, inasmuch as they have the greatest effect on the development of the outer


N
NE
NW
W
E
S
SW
SE
Axis of inner bulkhead & prop. jetty ext'n.
To sea
267.5 da.
141.0 da.
149.5 da.
76.5 da.
165.0 da.
251.0 da.
206.5 da.
342.0 da.
RESULTANT 304 DAYS.
No. of days from each direction
WIND CHART FOR 6 MONTHS OF HIGH RIVER (FEB. TO JULY BOTH INCLUSIVE) FOR CALENDAR YEARS 1909 TO 1917 BOTH INCLUSIVE.
THE DIAGRAMS WERE PLOTTED FROM THE OBSERVATIONS OF THE U.S. WEATHER BUREAU AT BURRWOOD, LA. WHICH WERE MADE AT 7:00 A.M. & 7:00 P.M. EACH DAY DURING THIS PERIOD.
DIRECTION OF WIND IS TOWARD CENTER OF DIAGRAM.
SEE SHEET NO. 18 FOR TABULATION OF RESULTS.
N
NE
N.W.
W
E
S
S.W.
SE
Axis of inner bulkhead & prop. jetty ext'n.
To sea.
420.5 da.
RESULTANT 515 DAYS.
282.5 da.
192.0 da.
68.0 da.
183.5 da.
124.0 da.
91.5 da.
262.5 da.
No of days from each direction.
WIND CHART FOR 6 MONTHS OF LOW RIVER (JAN., AND AUG. TO DEC., BOTH INCLUSIVE) FOR CALENDAR YEARS 1909 TO 1917, BOTH INCLUSIVE.
SHEET No. 19
WIND CHARTS
HIGH & LOW RIVER PERIODS
CALENDAR YEARS
1909 TO 1917 BOTH INCLUSIVE.
SCALE: AS NOTED

channel. During this period, the prevailing wind is from a direction nearly Southeast. This wind banks the water in the East Bay and blows it out of the West Bay, causing a superelevation in the former locality of the water surface at A on the drawing. There is also a superelevation at A′ where the river water issues from the ends of the jetties in the form of a mound. These areas of high elevation are bounded approximately by the dotted line. In the West Bay, at B, there is a large area of low elevation. The water issuing from the ends of the jetties has the energy due to jetty confinement and for a short distance in front of the jetties tends to spread out in fan-like shape. After losing this energy, it turns to the westward to seek the lower level in the West Bay. The banked water at A in the East Bay also tends to seek the lower level at B. In seeking this lower level, the surface water cannot flow back against the pressure of the easterly wind, and there must be a movement of the underlying water generally towards the West Bay. This movement will be as indicated by the arrows. When these undercurrents come near the bank of the issuing river water at A′, due to the superelevation of the latter, they cannot cross the face of the jetties directly, but are forced around the fan in front of the jetties, as shown by the arrows. The movement of the water in the East Bay is analogous to that in the trough shown in the upper left corner of this drawing. The gate C corresponds to the pressure of the Easterly wind. In restoring equilibrium between the water on each side of this gate, the surface water cannot flow back on account of the pressure of the gate, and the movement will be that of the sub-surface water, as indicated. Of course, further seaward on the East side there must be an area of low elevation at D, but this elevation is probably not as low as at B, as the bank of water on the East side probably extends much further seaward than shown by the dotted lines. The different conditions cannot be portrayed with exactness; it is believed that this drawing represents approximately the prevailing conditions of the cause and distribution of the sub-surface flow.

Where the currents from the bay strike these issuing from the river near the jetty ends, we would expect eddies; many of the observations show these eddies.

During low river the mound of water at the jetty entrance must be nearly entirely eliminated; during this period, also, the prevailing wind is from a direction in the Northeast quadrant.



ADVANCE OF 35 FT. CURVE, (FT.)			
PERIOD	E. SECTOR	W. SECTOR	% BY WHICH ADVANCE IN W. SECTOR EXCEEDS THAT IN E. SECTOR.
1839-1867	6,010	7,180	19.5
1867-1898	3,620	5,230	44.5
1898-1916	2,180	2,930	34.4
1839-1916	11,810	15,340	30.0

35 FT. CURVES FOR 1839 & 1867 ARE PLOTTED FROM COAST SURVEYS OF THOSE DATES; FOR 1898, FROM THE SURVEY MADE UNDER THE DIRECTION OF THE BOARD OF ENGINEER OFFICERS, & FOR 1916, FROM THE SURVEY BY THE U.S. ENGINEERS.
THE AREA OF DEPOSIT IS DIVIDED INTO 2 EQUIANGULAR SECTORS ONE ON EACH SIDE OF THE AXIS OF OUTFLOW AND THE AVERAGE ADVANCE FOR ANY PERIOD IS THE MEAN OF A LARGE NUMBER OF MEASUREMENTS MADE ALONG RADII BETWEEN THE CURVES

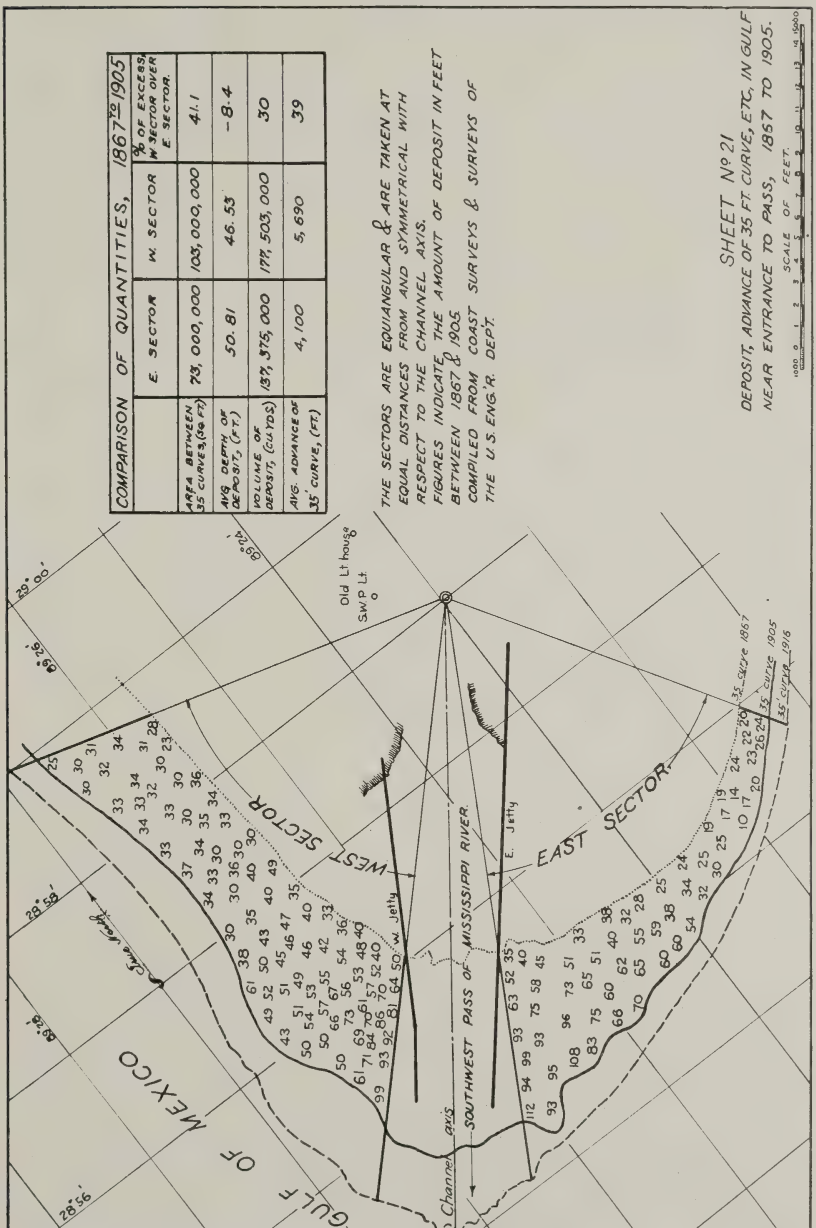
SHEET Nº 20
ADVANCE OF OUTER 35 FT. CURVES
1839 TO 1916

Under these conditions, during this period the current would not have as decided a westerly set as during the high water period. After an easterly or southeasterly wind during this period, due to the elimination of the mound of water at the jetty entrance, the sub-surface flow would be directly across the face of the jetties. However, the prevailing flow would probably make an angle of about 25 degrees, measured on the lower west side of the jetty axis, with the latter.

The distribution of the sediment, as in the case of the surface currents, verifies absolutely the prevalence of a westerly flow of the undercurrents. In this connection we will examine sheet No. 45, where the deposits in sections 4,000 feet East and West of the channel axis are compared. The sections were chosen this close to the jetty axis for the reason that, as stated before, the sub-surface current has its velocity arrested first and deposits its material closer inshore. Between 1898 and 1909, a period in which there was practically no jetty action, the deposit along the west section in a unit of width exceeded that along the East section by 24 9 per cent. In the period from 1909 to 1917, during the entire time of which the jetties were effective, the percentage of excess, as before, is 184.0. In either case the prevailing deposit is to the West; after the jetties were constructed, however, this prevailing westerly deposit was greatly increased, due to the design of the outer works to throw the current to the West, and due to the fact that the jetty confinement increased the size of the bottom load which the current was able to carry. The lesser deposit in the period from 1898 to 1909 is due also in some measure to the fact that during this period the axis of outflow was more to the east than in the period from 1909 to 1917. A scour near the outer end of the east section between 1909 and 1917 shows plainly that there must have been very little easterly movement of the sub-surface water.

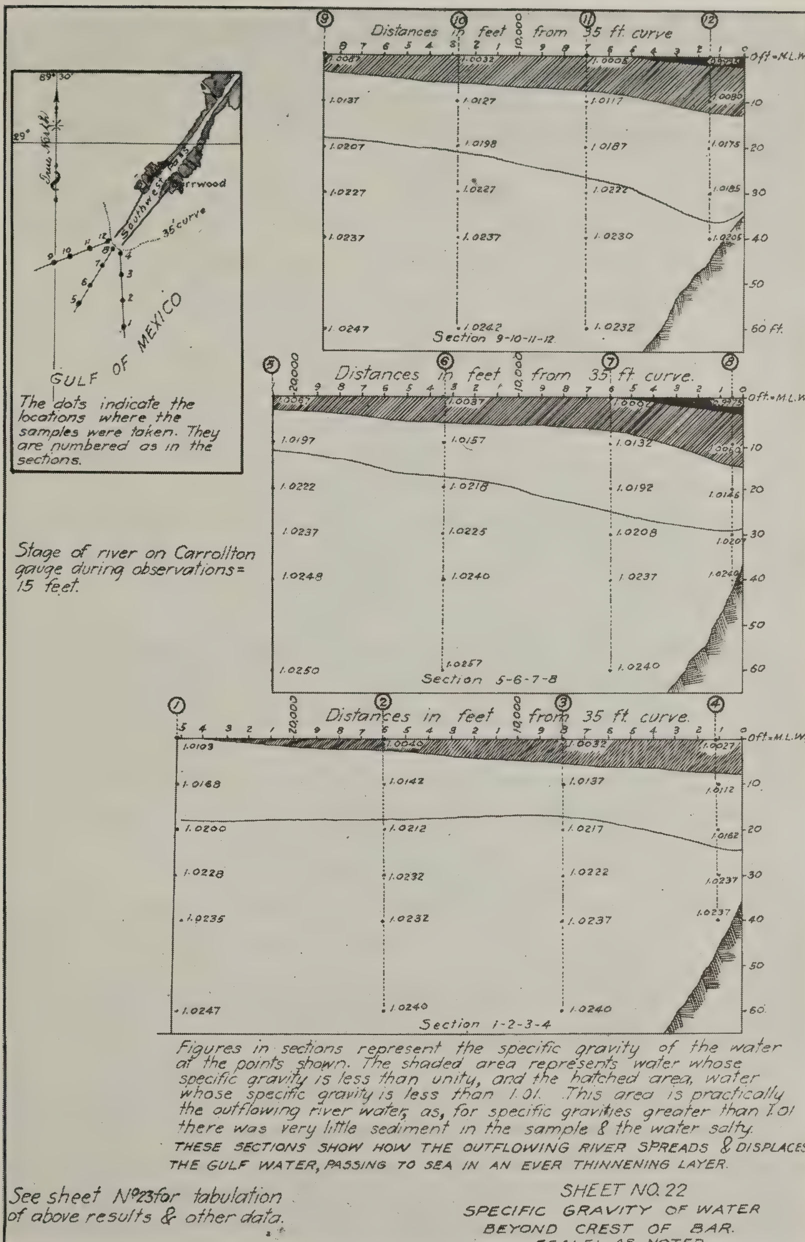
Sheet No. 46 shows the distribution of the river sediment in the area immediately beyond the ends of the jetties. The drawing on the left side shows this for the period 1909 to 1915, and that in the upper right corner for the period from 1898 to 1909. During the former period the jetties were fully effective, while during the latter the jetties were either not yet built or not fully effective, except during the latter two years of this period.

As stated before, the amount of deposit in this rectangle is only about 5 per cent or less of the total sediment that passed the



COMPARISON OF QUANTITIES, 1867 TO 1905	E. SECTOR	W. SECTOR	% OF EXCESS, W. SECTOR OVER E. SECTOR.
AREA BETWEEN 35' CURVES, (SQ. FT.)	73,000,000	103,000,000	41.1
AVG. DEPTH OF DEPOSIT, (FT.)	50.81	46.53	-8.4
VOLUME OF DEPOSIT, (CU. YDS.)	137,375,000	177,503,000	30
AVG. ADVANCE OF 35' CURVE, (FT.)	4,100	5,690	39

ends of the jetties; this undoubtedly represents the heavier material rolled along the bottom and part of that carried in suspension in the bottom current. The distribution of this deposit, therefore, should be an indication of the direction of the undercurrent. The average annual deposit in this area in the period March, 1898, to June, 1909, when there was very little jetty action, was almost 25 per cent greater than during the period June, 1909, to June, 1915, when the jetties were fully effective, showing that the increased velocity due to jetty confinement throws this material further to sea. During the period June, 1909, to June, 1915, the deposit to the west of the axis of outflow is much greater than that to the east of this axis, as a glance at the drawing will show, verifying that there existed a prevailing westerly set of the under currents. However, in the period from March, 1898, to June, 1909, in the same area, the sediment seems to be more uniformly distributed, with a prevalence on the eastern side, if the whole rectangle is considered. However, it must be remembered that during this period the outflow at the end of the Pass was much weaker than after the jetties were constructed, and the velocity of the undercurrents was arrested much closer inshore than in the latter period. If we compare the amount of deposit in the rectangle, 1,000 feet wide and 8,000 feet long, on the West side of the central rectangle with that in the rectangle of the same size, similarly placed on the East side, the former, 9,762,000 cubic yards, exceeds the latter, 8,733,000 cubic yards, by 13 per cent. It is most probable, however, that the sub-surface flow during this period was not strong enough to carry the heavier material held in suspension and that rolled along the bottom as far seaward as the area under consideration. The prevailing deposit on the east side would then indicate more a strong and prevailing westerly flow, for the weaker and occasional easterly currents would deposit their detritus closer to the axis of outflow, while the stronger and prevailing westerly currents would spread their burden of sediment over a larger area and further in proportion to the west of the axis of outflow. The areas under consideration, therefore, show the prevailing flow for the bottom current for the period 1909 to 1915, in which heavier materials were carried in suspension and rolled along the bottom, than in the period 1898 to 1909, during which period the distribution of the sediment would apply more to that carried in suspension near the bottom, which would require a smaller velocity to keep it from


89° 30'
29°
True North
Southwest Pass
Burrwood
35' curve
GULF OF MEXICO
The dots indicate the locations where the samples were taken. They are numbered as in the sections.
Stage of river on Carrollton gauge during observations = 15 feet.
Distances in feet from 35 ft. curve
0 ft. = M.L.W.
Section 9-10-11-12.
Section 5-6-7-8
Section 1-2-3-4
Figures in sections represent the specific gravity of the water at the points shown. The shaded area represents water whose specific gravity is less than unity, and the hatched area, water whose specific gravity is less than 1.01. This area is practically the outflowing river water, as, for specific gravities greater than 1.01 there was very little sediment in the sample & the water salty.
THESE SECTIONS SHOW HOW THE OUTFLOWING RIVER SPREADS & DISPLACES THE GULF WATER, PASSING TO SEA IN AN EVER THINNENING LAYER.
See sheet Nº23 for tabulation of above results & other data.
SHEET NO. 22
SPECIFIC GRAVITY OF WATER BEYOND CREST OF BAR.
SCALE: AS NOTED

depositing. If for the period, March, 1898, to 1909, larger areas extending further on the sides of the end of the Pass were considered, as on sheets Nos. 20 and 21, there would, as on the latter sheets, probably be shown a greater amount of deposit in the area to westward, indicating then a prevailing westerly flow.

. . . .

The prevailing westerly current has no doubt been accelerated, since the construction of the jetties and dikes, in the area influenced by the outflow from the ends of the jetties.

In order to study the velocity of the sub-surface flow, tabulations have ben prepared. Table No. 1[1] gives the average of the velocities of all the floats in each set of observations for the first 66,000 feet of travel. . . . Table No. 2[1] gives the averages of the velocities for the first 6,000 feet of travel of all the floats started from the same point. The average of the condition of tide and stage of river is also given in both tabulations.

For purposes of comparison, table 1-A[1] and 2-A[1] are given, showing the same data for the surface currents as given in tables 1 and 2, respectively, for the sub-surface currents.

. . . .

From table No. 1 it is seen that the average velocity of the sub-surface currents represented by these floats is 0.96 foot per second; the similar average for the surface floats, as shown in table No. 1-A, is 2.58 feet per second, showing that the sub-surface currents, on the average, are much weaker than the surface currents. . . .

In regard to the velocity of sub-surface flow, the influence of outflow near the jetty ends greatly increases the velocity of those sub-surface currents coming within this influence. . . The average velocity of the surface currents at these locations, as shown by table 2-A, is 2.22 feet per second, or about 2½ times as great as the sub-surface.

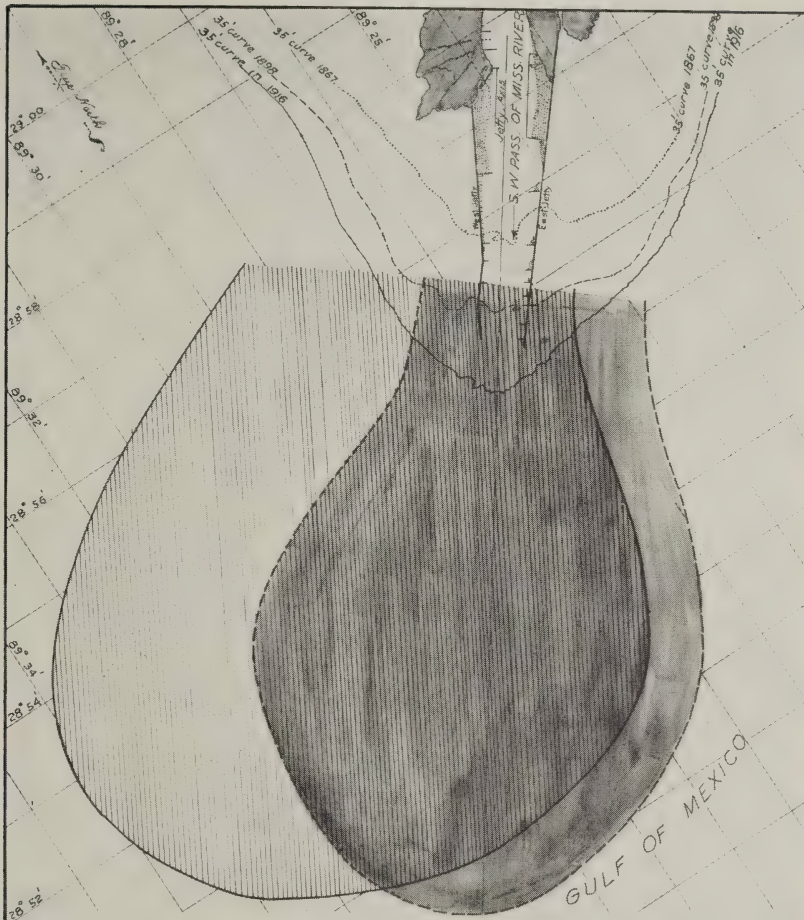
From table No. 2 it is seen that float No. 16 shows the greatest velocity of sub-surface flow. . . .

. . . .

. . . it appears that below the surface layer the mass of underlying water moves as a whole, or there is very little relative movement of the different strata of water below the surface.

The matter of table No. 1 seems to indicate that the stage of river or condition of tide has little effect on the velocity of sub-surface flow beyond the influence due to jetty confinement. . . .

[1]Not reproduced.



The heavy line bounding the hatched area represents the line of demarkation between the muddy outflowing river water and the clear gulf water during a moderately high river with a light easterly wind. The broken line, bounding the shaded area represents the same during a light westerly wind. The location of these lines is based on the observations on sheets Nos. 22 & 23 and on the observations of Pilots, Masters of dredges, etc., from an experience extending over many years.

SHEET No. 24

LINE OF DEMARKATION

BETWEEN

RIVER AND GULF WATER

Scale of feet

That the difference in the elevation of the water surfaces in the two bays on each side of the Pass is the main factor influencing the velocity of flow, is logical. This difference in elevation is in turn governed by the duration and intensity of winds from directions that would tend to bank this water. . . .

From the foregoing, the causes and distribution, etc., of the sub-surface flow in the Gulf beyond the ends of the jetties may be summarized as follows:

(1) During an extreme high stage, the river water displaces the seawater from the surface to the bottom as far seaward as the 35-foot curve, or approximately 3,000 feet from the ends of the jetties. Before the construction of the jetties, this ability of the river water to displace the sea water was considerably less. The sub-surface currents within the limits of the outflowing river water are generally the same in direction as the surface currents, a fan-like spread, with a tendency to the westward due to the design of the outer works. The velocities of the undercurrents within this area are less than half as great as the surface currents. The former velocities, however, are on the average about 2½ times as great as the undercurrents in the Gulf beyond the influence of river outflow.

(2) The direction of the currents in the latter area is variable; the prevailing direction is westerly, . . .

(3) The velocity of the underflow increases with the difference in the elevations of the water surfaces in the East and West Bays; this difference increases with the strength and duration of winds that tend to bank this water in the Bays. . . .

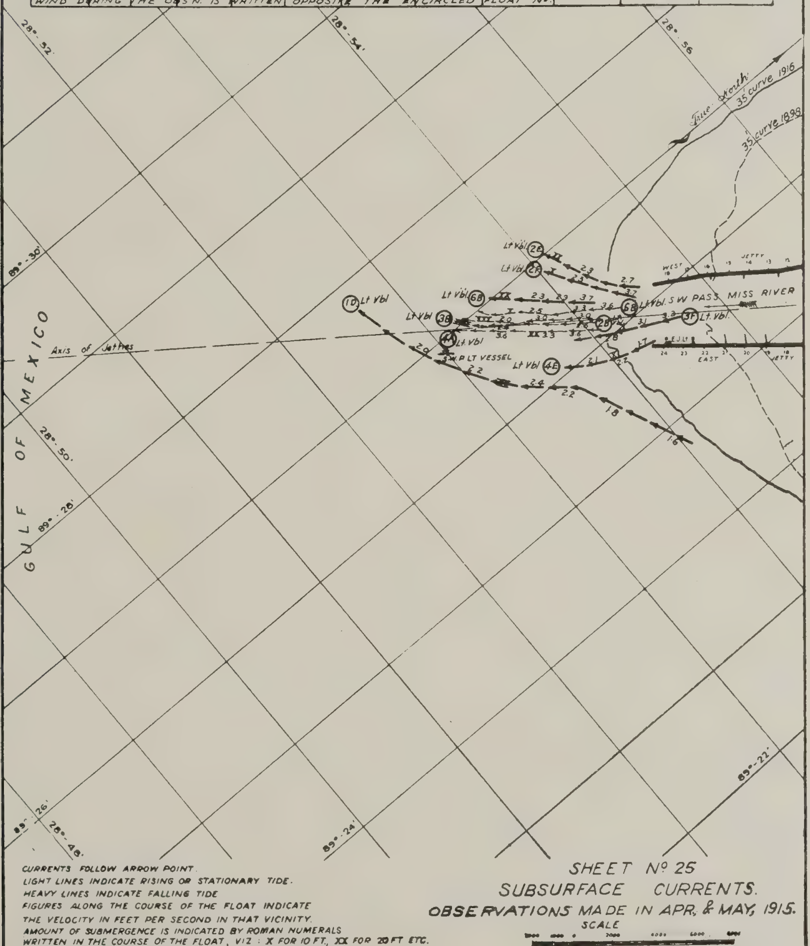
(4) During high river the westerly set of the undercurrents is more marked than during low river, ...

(5) The prevailing sub-surface flow during high river is exemplified by float No. 1-D on sheet No. 25; this direction makes an angle of about 45 degrees with the axis of the jetties measured on the lower west side of this axis. Further seaward the direction of the sub-surface flow is more nearly parallel to the face of the jetties.

(6) During low river the currents are more variable in direction, since the prevailing winds during this period are such that would not have a strong tendency to bank the water in either of the bays.

Float No	Am't of submergence (Ft)	Date of Obs	General Direction of travel	Prev wind for 3 days prior to Obs	Prev wind for 10 days prior to Obs.	Carrollton gauge (Ft) (R. S or F)	Burrwood gauge (Ft)	Cond'n of tide R=rising, F=falling, S=St'y	Rate of change of tide in 1/100 ft per hour	Avg vel of float for 1st 6000 ft of travel in f/s.	Avg vel of float for entire observation
4-A	20	Apr 27/15	SW'ly	E'ly	E'ly	7.80-S	4.0	S.	0	3.5	3.5
2-B	30	" 28/15	"	SE'ly	"	7.80-S	4.2	S.	0	2.2	2.2
3-B	40	"	"	"	"	7.80-S	4.2	S.	0	2.7	2.7
5-B	10	"	"	"	"	7.80-S	4.2	S.	0	3.0	3.0
6-B	20	"	"	"	"	7.80-S	4.2	F.	8	3.0	3.0
1-D	20	May 5/15	"	"	"	7.80-S	4.3	F.	4	2.0	2.0
2-E	20	" 8/15	"	S'ly	v'ble	8.50-S	4.1	F.	5	2.5	2.5
4-E	10	"	"	"	"	8.50-S	4.1	F.	5	2.0	2.0
2-F	10	" 10/15	"	"	"	7.80-S.	4.2	F.	8	3.2	3.2
3-F	10	" 10/15	"	"	"	7.80-S.	4.2	F.	8	3.0	3.0

WIND DURING THE OBS'N. IS WRITTEN OPPOSITE THE ENCIRCLED FLOAT No.



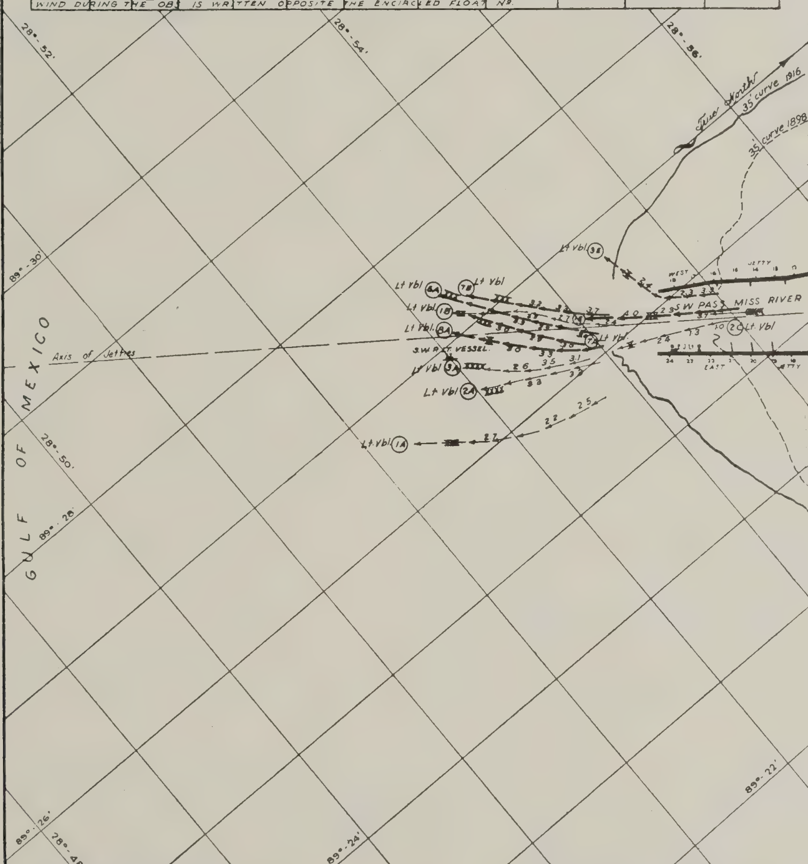
The observations show in general that both the surface and sub-surface currents are of sufficient strength to carry the suspended sediment a considerable distance seaward from the jetty ends; that the present works are too far apart to give the sub-surface flow sufficient energy to carry the heavier and coarser material over the bar and cause this deposit a considerable distance seaward on the sea slope of the bar. This is borne out by a large amount of data that shows that 95 per cent of the sediment, that carried in suspension, is deposited over a large area mostly to the westward of the axis of the jetties, and extending a considerable distance seaward, and that the heavier and coarser sediment that rolled along the bottom and part of that carried in suspension in the undercurrents, is deposited immediately in advance of the bar, causing a considerable advance of the bar from year to year. This latter sediment amounts only to about 5 per cent of the total that passes the ends of the jetties, and there is no doubt that the proposed inner bulkheads and extension of the outer jetties along parallel lines 2,400 feet apart will cause such an energy of outflow from the jetty ends to deposit the heavier material a considerable distance seaward and more under the influence of the prevailing westerly current in the sea, provided the flow through the Pass is not decreased. In order to adequately control the flow through the three main passes of the river, it is necessary to carry out the proposed new work in the lower portion of Southwest Pass in such a manner as not to increase the resistance to the flow any more than is absolutely necessary, and at the same time install such regulation works at the Head of Passes as will assist in restoring the normal flow through South Pass and Pass-a-Loutre. At the present time there through Southwest Pass and restrain to a corresponding extent the flow through South Pass and Pass-a-Loutre. At the present time there is authorized a system of spur dikes and submerged deflecting dikes at Head of Passes to assist in regulating the flow through the Passes. These dikes were authorized in sub-project approved October 8, 1917 (E. D. 102125/11), which gives the work in detail. Work on the dikes is now in progress and is expected that it will be completed before the high water of 1919.

(*b*) Observations of currents in the lower portion of Southwest Pass were made in May and June, 1918, and the paths of the currents are shown on plates Nos. 49 to 54.

On plates Nos. 49 and 50 of the observations are shown the

Float No	Am't of submergence (Ft)	Date of Obs	General Direction of travel	Prev wind for 3 days prior to Obs	Prev wind for 10 days prior to Obs	Carrollton gauge (Ft) (R S or F)	Burrwood gauge (Ft)	Cond'n of tide R=rising, F=falling, S=Sty	Rate of change of tide in 1/100 ft per hour	Avg vel of float for 1st 6000 ft of travel in f/s	Avg vel of float for entire observation
1-A	40	Apr 27/15	SW'ly	E'ly	E'ly	780-S	4.0	S	0	2.3	2.3
2-A	40	"	"	"	"	780-S	4.0	S	0	3.3	3.3
3-A	40	"	"	"	"	780-S	4.0	S	0	3.1	3.1
6-A	30	"	W'ly	"	"	780-S	4.0	F	10	3.1	3.1
7-A	30	"	"	"	"	780-S	4.0	F	10	3.4	3.4
8-A	10	"	SW'ly.	"	"	780-S	4.0	F	10	3.0	3.0
1-B	20	" 28/15	"	SE'ly	SE'ly	780-S	4.2	F	8	2.5	2.5
7-B	30	"	"	"	"	780-S	4.2	F	8	3.4	3.4
2-C	10	May 1/15	"	Lt NW'ly	E'ly	760-S	4.8	S.	0	1.6	1.6
1-E	20	" 8/15	"	S'ly	"	850-S.	4.1	F	5	3.1	3.1
3-E	10	" 8/15	"	S'ly	V'ble	850-S	4.1	F	5	2.7	2.7

WIND DURING THE OBS IS WRITTEN OPPOSITE THE ENCIRCLED FLOAT No.



CURRENTS FOLLOW ARROW POINT.
LIGHT LINES INDICATE RISING OR STATIONARY TIDE.
HEAVY LINES INDICATE FALLING TIDE.
FIGURES ALONG THE COURSE OF THE FLOAT INDICATE THE VELOCITY IN FEET PER SECOND IN THAT VICINITY.
AMOUNT OF SUBMERGENCE IS INDICATED BY ROMAN NUMERALS WRITTEN IN THE COURSE OF THE FLOAT, VIZ: X FOR 10 FT., XX FOR 20 FT. ETC.

SHEET No 26
SUBSURFACE CURRENTS.
OBSERVATIONS MADE IN APR. & MAY, 1915.
SCALE

paths of surface currents. As all previous observations have shown, it is evident from these observations that the direction and velocity of surface flow in the river is plainly, and in marked degree, influenced by the wind during the observation. Floats Nos. 1 to 6, on plate No. 49, which were observed during an easterly wind, traveled across to the west side of the Pass, and floats Nos. 7 to 9, on this plate, during a westerly wind traveled across the Pass towards the east. The surface flow, however, to the depth that it is affected by the wind, is of very little importance in its relation to channel development, as this depth seldom exceeds two or three feet, in which only a small part of the river sediment is carried.

On Plate No. 50, which shows observations of the surface flow made during calm weather, the currents show a marked parallelism to the inner bulkheads in place and to the line joining the ends of the spur dikes. By comparing the currents on this plate with the observations made before the construction of the works proposed by the Board, on the drawings previously noted, it will be seen that even that part of the modified project completed to date has had considerable effect in straightening the currents, especially above and opposite Burrwood and opposite Stake Island. The general curvature of their paths is much more gentle; the tendency appears to be towards a general conformation to the ultimate banks of the 2,400-foot width of the modified project. In that portion of the Pass, between the inner bulkheads, these currents are almost exactly parallel to the bulkheads and to themselves; this, of course, is an ideal condition, and the one for which the works were designed.

Towards the lower end of the jetty channel the dikes recently constructed appear to have had some effect in correcting the tendency of the current to cross over towards the end of the west jetty.

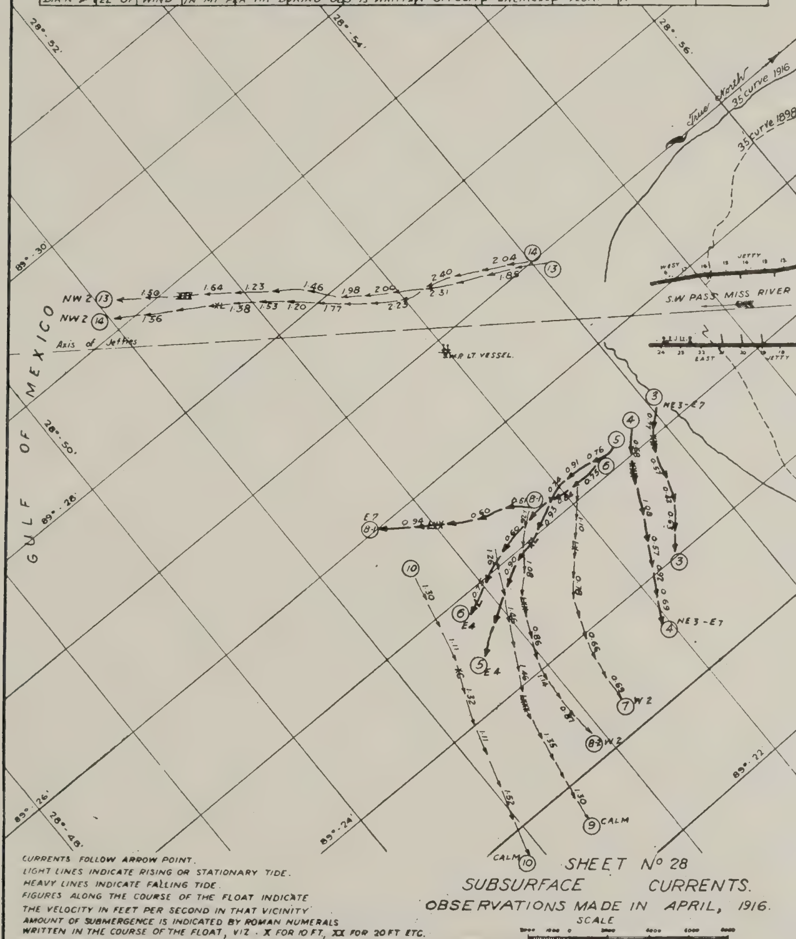
The currents, in general, show an increased velocity when passing through that part of the channel between the inner bulkheads now in place. Otherwise, the velocity, as all previous observations have shown, is affected by the stage of river, condition of tide, and direction and velocity of wind. The velocities of observations made under the same conditions show somewhat more uniformity than before the new works were constructed.

The sub-surface currents observed were at a depth of from

Float No.	Am't of submergence (Ft)	Date of Obs	General Direction of travel	Prev wind for 3 days prior to Obs.	Prev wind for 10 days prior to Obs.	Carrollton gauge (Ft) (R S or F)	Burrwood gauge (Ft)	Cond'n of tide R-rising, F-falling, S-Sty	Rate of change of tide in 1/100 ft per hour	Avg vel of float for 1st 6000ft of travel in f/s	Avg vel of float for entire observation
3	20	Apr 17/16	SE'ly.	* Lt Vble	W'ly	14 10 — S	4.38-3.80	F	21	0.57	0.57
4	30	" "	SE'ly	* "	"	14 10 "	"	"	21	0.80	0.80
5	40	" 18 "	S'ly	* "	"	14 30 "	4.70-4.35	F	11	0.84	0.88
6	50	" " "	"	* "	"	14.30 "	"	"	11	0.82	0.74
7	60	" 24 "	SE'ly.	N'ly	SE'ly	14 90 "	4.60-4.85	R.	7	1.03	0.83
8-1	70	" 18 "	SW'ly	* Lt Vbl	W'ly	14 30 "	4.35-3.70	F	14	0.68	0.68
8-2	70	" 24 "	SE'ly	N'ly.	SE'ly	14 90 "	4.60-4.85	R	7	1.00	1.00
9	80	" " "	"	"	"	14 90 "	4.25-4.60	R	14	1.35	1.36
10	90	" " "	"	"	"	14 90 "	"	"	14	1.22	1.47
13	30	" 17 "	SW'ly.	* Lt Vble	W'ly.	14.10 "	4.43-4.50	"	2	2.08	1.73
14	40	" " "	"	"	"	14 10 "	"	"	2	2.12	1.74

* Lt. Vble for 6 days prior & marked W'ly for 3 days prior to this.

DIR'N & VEL OF WIND IN MI PER HR DURING OBS IS WRITTEN OPPOSITE ENCIRCLED FLOAT No.



¼ to ½ of the depth of the water. These observations are shown on plates Nos. 51 to 54, both inclusive.

These currents also show a marked parallelism and tendency to conform to the new works in place in the main channel, and in the upper portion of the jetty channel. Some of the observations, especially those on plate No. 52, still show a westerly set of the current in the lower end of the jetty channel. However, it is believed that this condition will be remedied, at least in great part, when the extensions to dikes Nos. 11 and 13 are effective, and when the raising of the outer portions of the jetties, now being executed by contract, is completed. The necessity for a submerged mattress dike on the west side between dike No. 9 and the end of the west jetty is indicated by these observations. (The dike was proposed and is shown on plate No. 23 accompanying Major Schultz's Memoirs on the Passes.) The strong tendency of the current towards the end of the west jetty on plate No. 52 is no doubt caused to some extent by the strong southeast wind which obtained during the observation, causing a low elevation of the water surface in the west bay towards which the river water would flow in accordance with natural laws.

Several of the observations show a tendency of the currents to spread when passing the lower ends of the bulkheads in place. This is but natural; the extension of the bulkheads, now under way, will no doubt correct this.

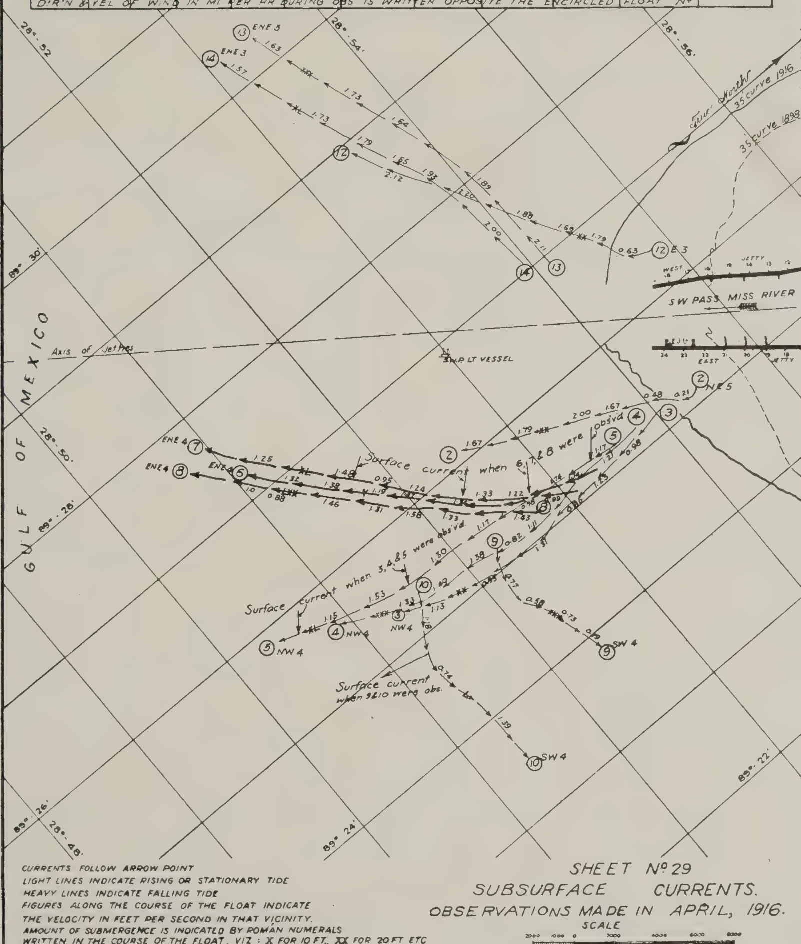
The velocities of the sub-surface currents still show a lack of uniformity even when the observations were made under the same conditions. This is no doubt due to the fact that the channel is now in a continual state of adjustment to the new works being constructed. It is believed, however, that the velocities are more uniform than those shown by the early observations before work on the modified project was started.

In general, the results of these observations are very encouraging, verifying, in a way, what would be expected theoretically, and indicating the correctness of the design of the modified project.

2. No observations were made at South Pass on account of the large amount of work by hired labor and the taking of discharge observations, which required the entire time of the engineering force and plant connected with that Pass. Furthermore, on account of losing engineers in the draft, and by better inducement being offered by industrial concerns, it has been impossible

Float No	Am't of submergence (Ft)	Date of Obs	General Direction of travel	Prev wind for 3 days prior to Obs	Prev wind for 10 days prior to Obs	Carrollton gauge (Ft) (R S. or F)	Burrwood gauge (Ft)	Cond'n of tide R=rising, F=falling, S=Sty	Rate of change of tide in 1/100 ft per hour	Avg vel of float for 1st 6000 ft of travel in f/s	Avg vel of float for entire observation
2	20	Apr 25/16	SW'ly.	Lt N'ly	SE'ly.	14.95 – R	4.45 – 4.77	R	11	0.63	0.98
3	20	" 22 "	S'ly	Mkd SE'ly.	E'ly	14.85 – R	4.40 – 5.05	"	15	1.06	1.08
4	30	" " "	"	"	"	" "	" "	"	15	1.20	1.21
5	40	" " "	SW'ly.	"	"	" "	" "	"	15	1.43	1.29
6	50	" " "	"	"	"	" "	5.10 – 4.65	F	12	1.22	1.27
7	60	" " "	"	"	"	" "	" "	"	12	1.24	1.20
8	70	" " "	"	"	"	" "	" "	"	12	1.47	1.24
9	30	" 24 "	SE'ly.	N'ly	SE'ly.	14.90 "	4.85	S	0	0.73	0.74
10	50	" " "	"	"	"	" "	"	"	0	0.85	1.04
12	20	" 25 "	SW'ly	Lt "	"	14.95 "	4.78 – 4.90	R	7	1.52	1.68
13	30	" 21 "	W'ly	Mkd SE'ly.	E'ly.	14.80 "	5.00	S	0	2.03	1.80
14	40	" " "	"	"	"	" "	"	"	0	1.97	1.76

DIR'N & VEL OF WIND IN MI PER HR DURING OBS IS WRITTEN OPPOSITE THE ENCIRCLED FLOAT No



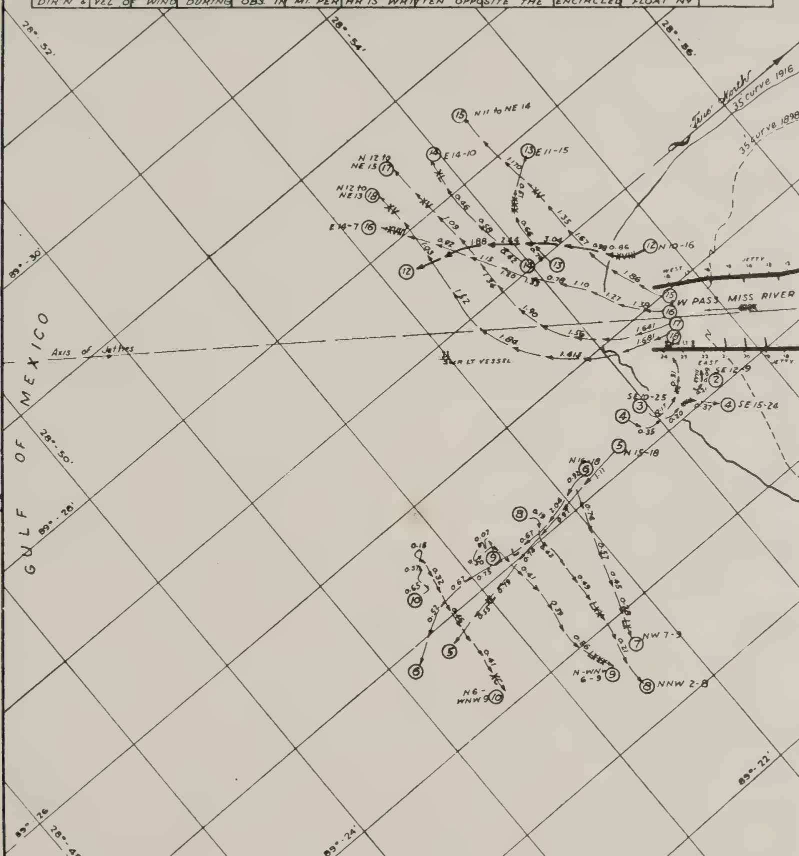
SHEET No 29
SUBSURFACE CURRENTS.
OBSERVATIONS MADE IN APRIL, 1916.

to maintain an adequate force of engineers at South Pass during the past year.

In view of the fact that observations taken in the spring of 1916 at South Pass show no marked change from the currents at Southwest Pass, aside from the velocity of the outflowing river water, and in view of the further fact that it is impracticable to maintain a properly trained organization, under present conditions, to carry on the current observation, I would recommend that the making of current observations at South Pass be indefinitely postponed.

Float No	Am't of submergence (Ft)	Date of Obs	General Direction of travel	Prev wind for 3 days prior to Obs.	Prev. wind for 10 days prior to Obs.	Carrollton gauge (Ft) (R. S. or F.)	Burrwood gauge (Ft.)	Cond'n of tide R-rising, F-falling, S-Sty	Rate of change of tide in 1/100 ft per hour	Avg vel. of float for 1st 6000 ft of travel in f/s.	Avg vel of float for entire observation
2	18	Jan 12/17	Eddy action	Strong W'ly.	SW'ly.	4.60 — R	3.25 – 3.20	F	4	0.12	0.12
3	20	" "	"	"	"	" "	3.22 – 3.29	R	3	0.27	0.27
4	30	" " "	"	"	"	" "	3.28 – 3.45	"	5	0.28	0.28
5	40	25 "	S E'ly	NE'ly.	NE'ly.	9.80 "	3.75 – 3.92	"	5	0.82	0.77
6	50	" " "	S'ly	"	"	" "	" – "	"	4	1.06	0.79
7	60	" 8 "	SE'ly	N'ly.	SE'ly	1.85 S	3.25 – "	"	17	0.45	0.45
8	70	" " "	E'ly	"	"	1.90 "	2.69 – "	"	17	0.38	0.38
9	80	" " "	"	"	"	" "	2.41 – 4.30	"	15	0.29	0.35
10	90	" " "	"	"	"	" "	2.41 – 4.15	"	15	0.27	0.37
12	18	25 "	SW'ly	NE'ly	NE'ly	9.65 — R	4.50 – 4.03	F	26	1.25	1.50
13	30	Nov 13/16	W'ly	"	E'ly.	1.00 — S	3.63 – 3.94	R	20	0.64	0.64
14	40	" " "	"	"	"	" "	" "	" "	20	0.57	0.57
15	15	Jan. 19/17	"	"	NE'ly.	7.75 — R	3.24 – 3.83	"	19	1.77	1.12
16	18	Nov 13/16	SW'ly	"	E	1.00 — S	3.48 – 3.94	"	18	1.14	1.14
17	15	Jan. 19/17	W'ly	"	NE'ly	7.75 — R	3.20 – 3.80	"	19	1.60	1.44
18	15	" " "	"	"	"	" "	3.18 – 3.82	"	19	1.56	1.38

DIR'N & VEL OF WIND DURING OBS. IN MI. PER HR IS WRITTEN OPPOSITE THE ENCIRCLED FLOAT No.

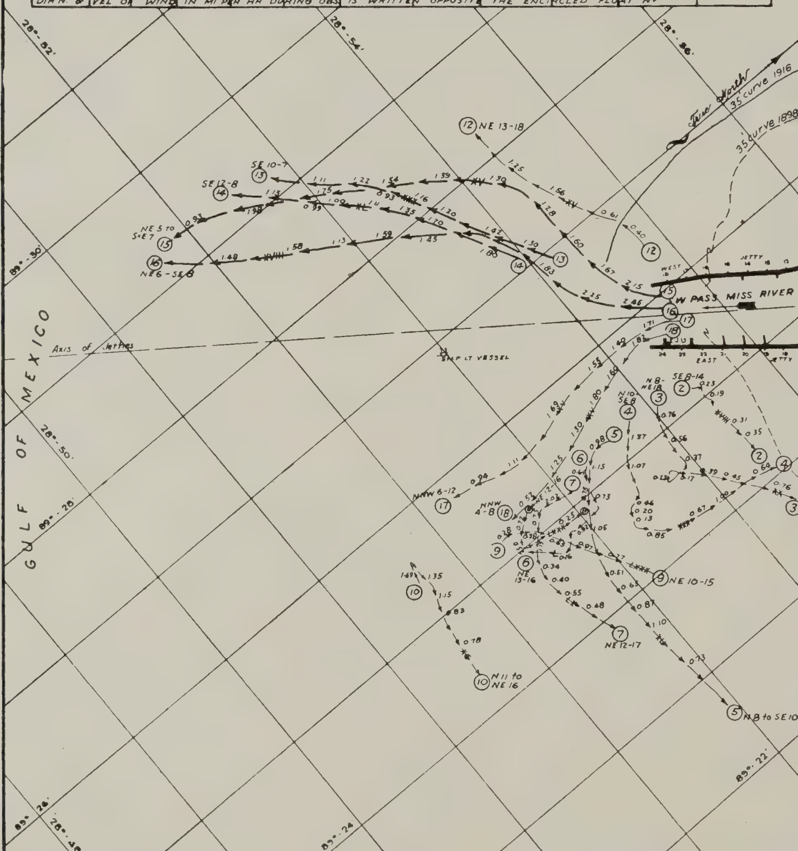


CURRENTS FOLLOW ARROW POINT.
LIGHT LINES INDICATE RISING OR STATIONARY TIDE.
HEAVY LINES INDICATE FALLING TIDE
FIGURES ALONG THE COURSE OF THE FLOAT INDICATE THE VELOCITY IN FEET PER SECOND IN THAT VICINITY
AMOUNT OF SUBMERGENCE IS INDICATED BY ROMAN NUMERALS WRITTEN IN THE COURSE OF THE FLOAT, VIZ: X FOR 10 FT., XX FOR 20 FT ETC.

SHEET No 30
SUBSURFACE CURRENTS.
OBSERVATIONS MADE IN NOV., 1916 & JAN., 1917.
SCALE

Float No.	Am't of submergence (Ft)	Date of Obs.	General Direction of travel	Prev wind for 3 days prior to Obs.	Prev wind for 10 days prior to Obs.	Carrollton gauge (Ft) (R S or F)	Burrwood gauge (Ft)	Cond'n of tide R-rising, F-falling, S-Sty	Rate of change of tide in 1/100 ft per hour	Avg vel of float for 1st 6000 ft of travel in f/s	Avg vel of float for entire observation
2	18	Mar. 30/17	E'ly	Lt E'ly	E'ly	12.83 - R	3.86 - 4.20	R	11	0.26	0.26
3	20	Feb. 6/17	"	NW'ly	N'ly	9.00 - S	3.22 - 3.80	"	10	0.40	0.50
4	30	" " "	"	"	"	" "	3.30 - 4.00	"	11	0.52	0.61
5	40	" " "	"	"	"	" "	3.37 - 3.74	"	11	0.98	0.85
6	50	Mar. 19 "	SE'ly	N'ly	E'ly	11.23 - R	3.31 - 3.50	"	6	0.50	0.50
7	60	" " "	E'ly	"	"	" "	3.31 - 3.62	"	10	0.77	0.69
8	70	" " "	NE'ly	"	"	" "	3.62 - 3.90	"	8	0.36	0.36
9	80	" " "	"	"	"	" "	3.74 - 3.97	"	7	0.50	0.50
10	90	" " "	E'ly	"	"	" "	3.97 - 4.13	"	12	1.10	1.10
12	15	" " "	W'ly	"	"	" "	3.31 - 3.62	"	10	0.95	1.01
13	30	Feb. 10 "	SW'ly	"	N'ly	9.95 - S	3.85 - 3.80	F	15	1.32	1.20
14	40	" " "	"	"	"	" "	3.85 - 3.83	"	0.7	1.64	1.29
15	15	" " "	"	"	"	" "	3.96 - 3.85	"	3	1.81	1.57
16	18	" " "	"	"	"	" "	3.96 - 3.80	"	3	2.20	1.63
17	15	" 9 "	S'ly	Variable	"	9.93 - S	4.00 - 4.02	R	1	1.56	1.41
18	15	" " "	SE'ly	"	"	" "	4.00 - 4.20	R	3	1.74	1.32

DIR'N. & VEL OF WIND IN MI PER HR DURING OBS. IS WRITTEN OPPOSITE THE ENCIRCLED FLOAT Nº

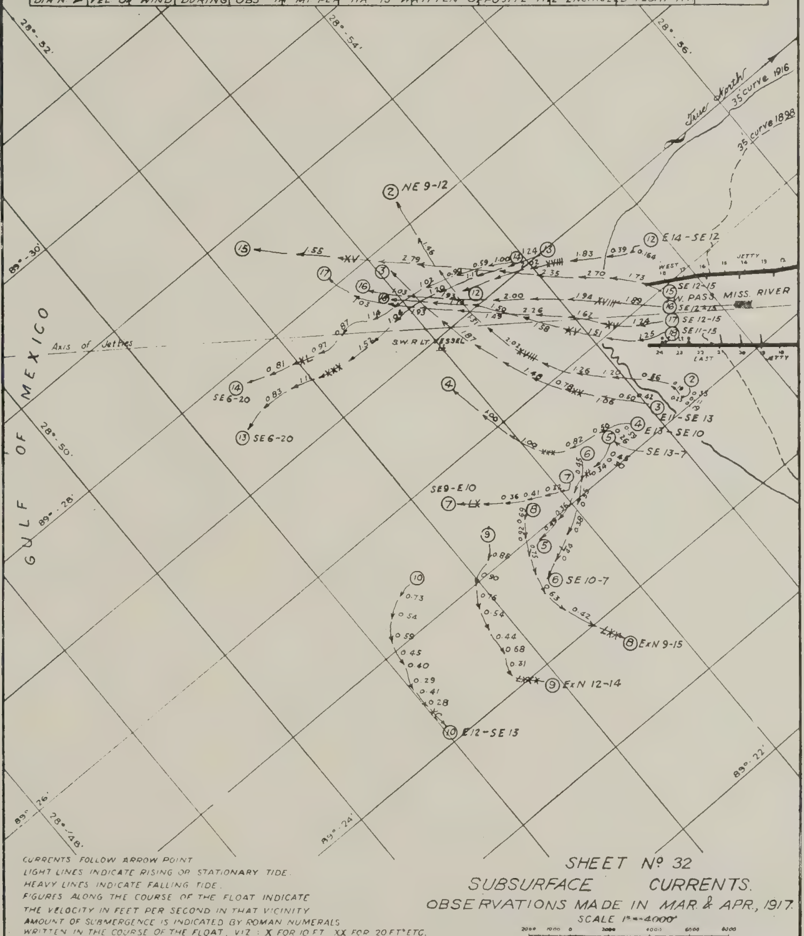


CURRENTS FOLLOW ARROW POINT
LIGHT LINES INDICATE RISING OR STATIONARY TIDE.
HEAVY LINES INDICATE FALLING TIDE
FIGURES ALONG THE COURSE OF THE FLOAT INDICATE THE VELOCITY IN FEET PER SECOND IN THAT VICINITY.
AMOUNT OF SUBMERGENCE IS INDICATED BY ROMAN NUMERALS WRITTEN IN THE COURSE OF THE FLOAT, VIZ: X FOR 10 FT., XX FOR 20 FT. ETC.

SHEET Nº 31
SUBSURFACE CURRENTS.
OBSERVATIONS MADE IN FEB. & MAR., 1917.

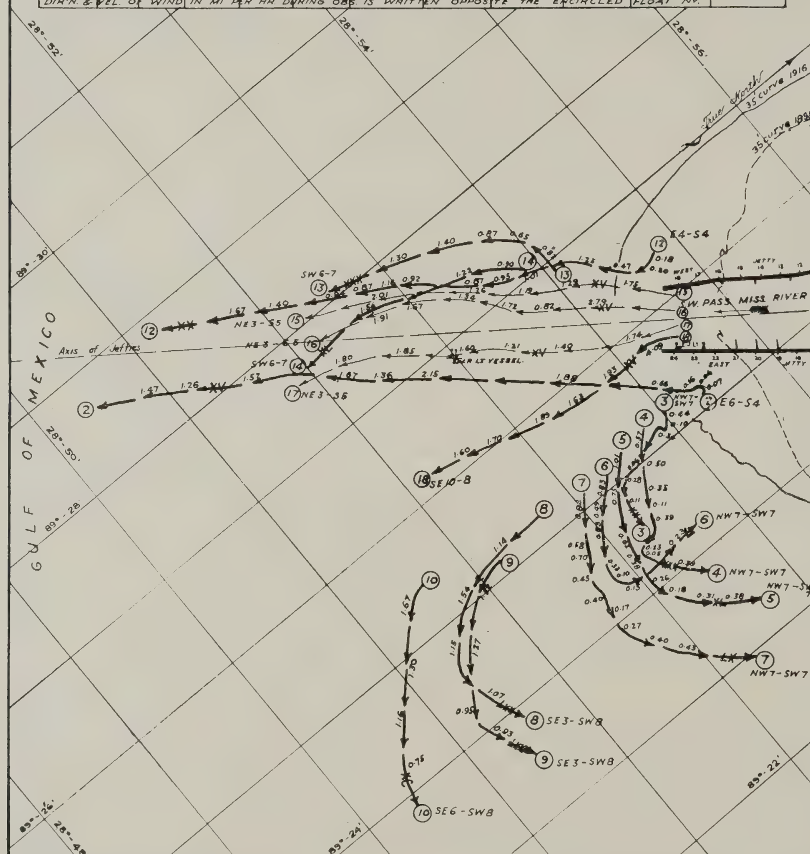
Float No	Am't of submergence (Ft)	Date of Obs	General Direction of travel	Prev wind for 3 days prior to Obs	Prev wind for 10 days prior to Obs	Carrollton gauge (Ft) (R S or F)	Burrwood gauge (Ft)	Cond'n of tide R-rising, F-falling, S-Sty	Rate of change of tide in 1/100 ft per hour	Avg vel of float for 1st 6000 ft of travel in f/s	Avg vel of float for entire observation
2	18	Mar 29/17	W'ly	Lt NE'ly	E'ly	12 70 – R	3.97 – 4.59	R.	9	0.32	0.73
3	20	" " "	"	"	"	"	4.41 – 4.59	"	6	0.84	1.10
4	30	" " "	"	"	"	"	4.50 – 4.60	"	5	0.70	0.73
5	40	" " "	S'ly	"	"	"	4.57 – 4.61	"	1	0.40	0.40
6	50	" " "	SE'ly	"	"	"	4.59 – 4.60	"	1	0.44	0.44
7	60	" " "	SW'ly	"	"	"	4.60 – 4.61	"	1	0.37	0.37
8	70	" 30 "	E'ly	Lt E'ly	"	12 83 – R	3.97 – 4.29	"	14	0.60	0.61
9	80	" " "	"	"	"	"	4.10 – 4.41	"	10	0.64	0.61
10	90	" " "	"	"	"	"	4.19 – 4.48	"	10	0.46	0.46
12	18	" " "	SW'ly	"	"	"	4.24 – 4.48	"	10	0.74	0.94
13	30	Apr 7 "	S'ly	W'ly	"	13 90 – R	4.09 – 4.18	"	03	1.20	1.15
14	40	" " "	"	"	"	"	4.12 – 4.21	"	3	0.88	0.92
15	15	Mar 30/17	SW'ly	Lt E'ly	"	12 83 – R	4.50 – 4.64	"	3	2.21	2.19
16	18	" " "	"	"	"	"	4.58 – 4.66	"	2	1.95	1.77
17	15	" " "	"	"	"	"	4.49 – 4.63	"	6	1.61	1.53
18	15	" " "	"	"	"	"	" "	"	6	1.40	1.48

DIR'N & VEL OF WIND DURING OBS IN MI PER HR IS WRITTEN OPPOSITE THE ENCIRCLED FLOAT No.



Float No	Am't of submergence (Ft)	Date of Obs.	General Direction of travel	Prev wind for 3 days prior to Obs.	Prev wind for 10 days prior to Obs.	Carrollton gauge (Ft) (R. S or F)	Burrwood gauge (Ft)	Cond'n of tide R=rising, F=falling, S=St'y	Rate of change of tide in 1/100 ft per hour	Avg. vel. of float for 1st 6000 ft. of travel in f/s	Avg. vel. of float for entire observation
2	15	Apr. 25/17	SW'ly	Lt. W'ly.	E'ly.	16.60 – S	4.95 – 4.79	F	16	1.04	1.03
3	20	23 "	SE'ly	N'ly.	"	16.70 – S	5.16 – 4.57	"	19	0.21	0.21
4	30	" " "	"	"	"	" "	5.19 – 4.59	"	19	0.37	0.32
5	40	" " "	E'ly	"	"	" "	5.21 – 4.48	"	19	0.65	0.38
6	50	" " "	"	"	"	" "	5.22 – 4.41	"	19	0.30	0.27
7	60	" " "	"	"	"	" "	5.24 – 4.40	"	19	0.59	0.42
8	70	" 24 "	SE'ly.	Lt. W'ly.	"	16.65 "	5.30 – 5.28	"	0.8	1.27	1.21
9	80	" " "	"	"	"	" "	5.30 – 5.26	"	1.5	1.29	1.13
10	90	" " "	"	"	"	" "	5.35 – 5.20	"	10	1.42	1.17
12	15	" 25 "	SW'ly.	"	"	16.60 "	5.09 – 4.70	"	16	0.56	0.87
13	30	" 24 "	S'ly.	"	"	16.65 "	5.10 – 4.49	"	21	0.95	1.02
14	40	" " "	"	"	"	" "	5.10 – 4.68	"	21	1.10	1.25
15	15	" 26 "	SW'ly.	"	"	16.55 "	4.84 – 5.12	R	10	1.53	1.51
16	15	" " "	"	"	"	" "	4.84 – 5.14	"	10	2.68	1.64
17	15	" " "	"	"	"	" "	4.71 – 5.10	"	10	1.65	1.61
18	15	" " "	S'ly.	"	"	" "	5.07 – 4.81	F.	10	2.37	1.96

DIR'N. & VEL. OF WIND IN MI PER HR DURING OBS. IS WRITTEN OPPOSITE THE ENCIRCLED FLOAT №.



CURRENTS FOLLOW ARROW POINT.
LIGHT LINES INDICATE RISING OR STATIONARY TIDE.
HEAVY LINES INDICATE FALLING TIDE.
FIGURES ALONG THE COURSE OF THE FLOAT INDICATE THE VELOCITY IN FEET PER SECOND IN THAT VICINITY.
AMOUNT OF SUBMERGENCE IS INDICATED BY ROMAN NUMERALS WRITTEN IN THE COURSE OF THE FLOAT, VIZ: X FOR 10 FT, XX FOR 20 FT. ETC.

SHEET № 33
SUBSURFACE CURRENTS.
OBSERVATIONS MADE IN APRIL 1917

SCALE

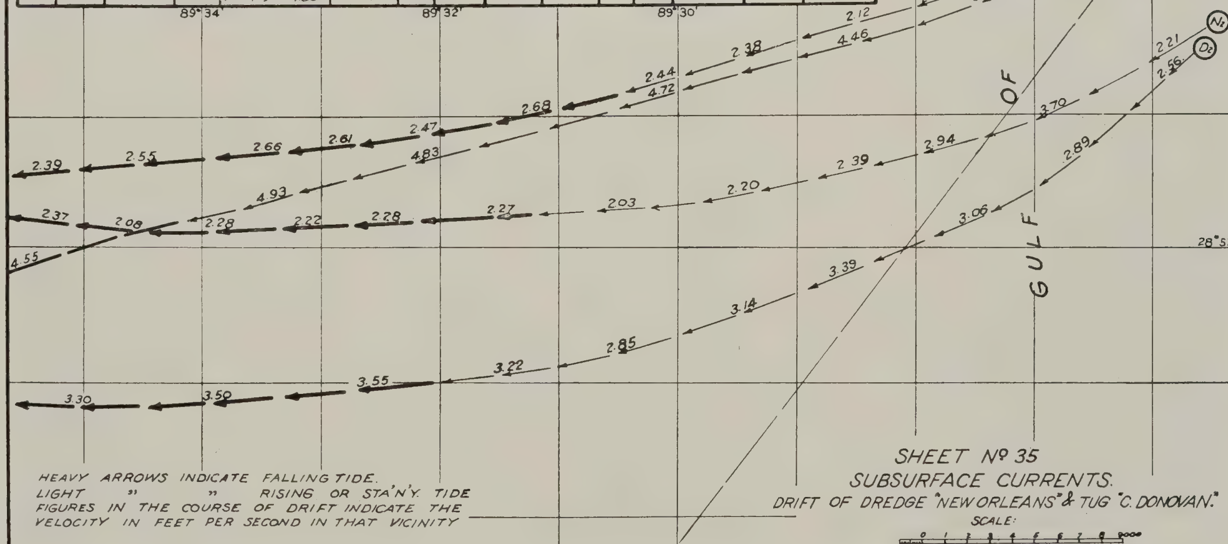
2000 1000 0 2000 4000 6000 8000

Float No	Am't of submergence (Ft)	Date of Obs.	General Direction of travel	Prev wind for 3 days prior to Obs	Prev wind for 10 days prior to Obs	Carrollton gauge (Ft) (R. S. or F)	Burrwood gauge (Ft)	Cond'n of tide R=rising, F=falling, S=Sty	Rate of change of tide in 1/100 ft per hour	Avg vel of float for 1st 6000 ft of travel in f/s	Avg vel of float for entire observation
1		Water	too	shoal	for	subsurface	float.	F	—	—	—
2	14	Aug. 16/17	E'ly.	Lt N'ly.	W'ly.	3.40 – F.	4.40 – 3.30	"	19	0.64	0.72
3	20	" 10 "	SE'ly.	W'ly.	"	4.80 – F.	4.00 – 3.42	"	20	0.36	0.56
4	30	" " "	"	"	"	" "	3.90 – 3.36	"	20	0.60	0.60
5	40	" " "	"	"	"	" "	3.85 – 3.36	"	20	0.97	0.97
6	50	" 13 "	"	"	N'ly.	4.13 "	4.30 – 3.00	"	18	0.78	0.76
7	60	" " "	"	"	"	" "	4.25 – 3.00	"	18	0.72	0.92
8	70	" " "	"	"	"	" "	4.06 – 3.00	"	18	0.75	0.94
9	80	" " "	"	"	"	" "	3.83 – 3.00	"	16	0.67	0.94
10	90	" " "	"	"	"	" "	3.48 – 3.00	"	16	0.79	0.74
11		Water	too	shoal	for	subsurface	float.	"	—	—	—
12	18	" 14 "	S'ly.	"	W'ly.	3.90 – F	4.66 – 3.20	"	18	0.43	0.60
13	30	" " "	SE'ly.	"	"	" "	4.00 – 3.20	"	18	1.11	1.04
14	40	" " "	S'ly.	"	"	" "	" "	"	18	1.06	1.08
15	15	" 11 "	SW'ly.	"	"	4.75 "	4.38 – 3.60	"	22	1.50	1.29
16	18	" " "	"	"	"	" "	" "	"	22	1.45	1.37
17	15	" " "	"	"	"	" "	4.43 – 3.60	"	22	1.58	1.40
18	15	" " "	"	"	"	" "	4.48 – 3.65	"	22	1.76	1.41
DIR'N. & VEL	OF WIND DURING OBS. IN MI. PER HR. IS WRITTEN OPPOSITE THE ENCIRCLED FLOAT No										

CURRENTS FOLLOW ARROW POINT.
LIGHT LINES INDICATE RISING OR STATIONARY TIDE
HEAVY LINES INDICATE FALLING TIDE.
FIGURES ALONG THE COURSE OF THE FLOAT INDICATE THE VELOCITY IN FEET PER SECOND IN THAT VICINITY.
AMOUNT OF SUBMERGENCE IS INDICATED BY ROMAN NUMERALS WRITTEN IN THE COURSE OF THE FLOAT, VIZ: X FOR 10 FT, XX FOR 20 FT. ETC.

SHEET No 34
SUBSURFACE CURRENTS.
OBSERVATIONS MADE IN AUGUST, 1917.
SCALE

No.	Date (1916)	Vessel	Mean Draft (ft.)	Tide - Burrwood gauge. R = rising, F = falling, S = stay	Wind during Obs. Direction	Wind during Obs. Vel. (M. pr. H.)	Carrollton gage (Ft.) R, S, or F.	Vel. of Drift (f/s) For entire Obs.	Vel. of Drift (f/s) For 1st 6000'	Time Drifted Hrs	Time Drifted Mn.	Distance drifted (Ft.)	Prev. Wind For 3 days prior to Obs.	Prev. Wind For 10 days prior to Obs.
N_1	July 31	U.S. Dredge New Orleans	21	R 5.00 - 5.05 S 5.05 F 5.05 - 4.50	NE x E to E x N to E	14 16 12	8.50-F	2.40	2.44	7	30	64,870	Strong E'ly	Strong E'ly.
D_1	July 31	U.S. Tug C. Donovan	9	R = 5.00-5.05 S = 5.05 F = 5.05-4.95	Ditto.	Do	Do.	4.79	3.91	3	19	57,200	"	"
N_2	Aug. 1	U.S. Dredge New Orleans.	20	R = 4.75-4.90 S = 4.90 F = 4.90-4.65	NE x E to E x N to E	6-10 5 5	Do.	2.38	2.71	7	0	59,910	"	"
D_2	Aug. 1	U.S. Tug C. Donovan	9	R = 4.75-4.90 S = 4.90 F = 4.90-4.80	NE x E to E x N	6-10 5	Do.	3.19	2.64	5	30	63,050	"	"



SHEET No. 35

SUBSURFACE CURRENTS.

DRIFT OF DREDGE "NEW ORLEANS" & TUG "C. DONOVAN."

In interpreting the relation between the dir'n of the prev wind for the 3 days prior to the obs'n. and that of the current, the effect of the river current was considered, especially near the jetty entrance and at the high stages of the river.

SUBSURFACE CURRENTS

Observation Nº.	Amt. of submergence (ft)	Date of Observation	Prevailing wind for 3 days prior to the observation	Direction of current.	Dir'n. of current plainly in accord with dir'n. of prevailing wind for 3 days prior to obs'n.	Dir'n of current partially or doubtfully in accord with dir'n of prev. wind for 3 days prior to obs'n.	Dir'n. of current apparently uninfluenced by prev. wind for 3 days prior to obs'n.	Gen'l. dir'n. of current (See sketch above.) Easterly	Westerly
1-A	30	4/27/15	E'ly	S.W'ly	/			/	
2-A	40	"	"	"	/				/
3-A	40	"	"	"	/				/
4-A	20	"	"	"	/				/
6-A	30	"	"	W'ly	/				/
7-A	40	"	"	"	/				/
8-A	10	"	"	S.W'ly.	/				/
1-B	20	4/28/15	SE'ly	"	/				/
2-B	30	"	"	"	/				/
3-B	40	"	"	"	/				/
5-B	10	"	"	"	/				/
6-B	20	"	"	"	/				/
7-B	30	"	"	"	/				/
1-D	20	5/5/15	"	"	/				/
†N-1	20	7/31/16	E'ly.	W'ly.	/				/
†N-2	20	8/1/16	"	"	/				/
‡D-1	10	7/31/16	"	"	/				/
‡D-2	10	8/1/16	"	"	/				/
2	20	4/25/16	N'ly.	SW'ly	/			/	
2	18	1/12/17	W'ly.	Eddy action	/			/	
*2	18	3/30/17	Lt. E'ly.	E'ly			/	/	
2	18	3/29/17	N.E'ly.	W'ly.	/				/
*2	15	4/25/17	Lt W'ly.	S.W'ly.			/		/
*2	14	8/16/17	Lt N'ly.	E'ly.		/		/	
3	20	4/10/16	W'ly.	S.E'ly.	/			/	
*3	20	4/17/16	Lt Variable	"		/		/	
3	20	4/22/16	S.E'ly.	S'ly		/		/	
3	20	1/12/17	W'ly.	Eddy action	/			/	
3	20	2/6/17	NW'ly.	E'ly.	/			/	
3	20	3/29/17	Lt NE'ly.	W'ly.	/				/
3	20	4/23/17	N'ly.	SE'ly.	/			/	
3	20	8/10/17	W'ly	"	/			/	
4	30	4/10/16	W'ly	E'ly.	/			/	
*4	30	4/17/16	Lt. Var'ble	SE'ly.		/		/	
4	30	4/22/16	SE'ly.	S'ly.		/		/	
4	30	1/12/17	W'ly	Eddy action	/			/	
4	30	2/6/17	NW'ly	E'ly	/			/	
4	30	3/29/17	Lt N.E'ly.	W'ly	/				/
4	30	4/23/17	N'ly	SE'ly	/			/	
4	30	8/10/17	W'ly.	"	/			/	
5	40	4/11/16	W'ly	E'ly.	/			/	
*5	40	4/18/16	Lt Var'ble	S'ly.		/		/	
5	40	4/22/16	SE'ly	S.W'ly.	/			/	
5	40	1/25/17	NE'ly.	S'ly	/			/	
5	40	2/6/17	N.W'ly.	E'ly.	/			/	
6	40	3/29/17	Lt NE'ly	S'ly.	/			/	
5	40	4/23/17	N'ly.	E'ly.		/		/	
5	40	8/10/17	W'ly.	SE'ly.	/			/	
6	50	4/11/16	"	E'ly	/			/	
*6	50	4/18/16	Lt Var'ble	S'ly		/		/	
6	50	4/22/16	SE'ly.	SW'ly.	/				/
6	50	1/25/17	NE'ly.	S'ly	/			/	
6	50	3/19/17	N'ly.	SE'ly.	/			/	
*6	50	3/29/17	Lt NE'ly.	"		/		/	
6	50	4/23/17	N'ly	E'ly.		/		/	
6	50	8/13/17	W'ly.	SE'ly.	/			/	
7	60	4/11/16	"	E'ly	/			/	
7	60	4/24/16	N'ly.	SE'ly.		/		/	
7	60	4/22/16	SE'ly.	SW'ly.	/				
7	60	1/8/17	N'ly	SE'ly		/		/	
7	60	3/19/17	"	E'ly.		/		/	
7	60	3/29/17	Lt NE'ly.	S W'ly.	/				
7	60	4/23/17	N'ly.	E'ly		/		/	
7	60	8/13/17	W'ly.	SE'ly.	/			/	

Observation Nº.	Amt. of submergence (ft.)	Date of Observation.	Prevailing wind for 3 days prior to the observation.	Direction of current.	Dir'n. of current plainly in accord with dir'n. of prev. wind for 3 days prior to obs'n.	Dir'n. of current partially or doubtfully in accord with dir'n. of prev. wind for 3 days prior to obs.	Dir'n. of current apparently uninfluenced by prev. wind for 3 days prior to obs'n.	Gen'l Dir'n. of current (See sketch above) Easterly	Westerly
	TOTALS	FORWARD			48	8	0	33	23
8	70	4/11/16	W'ly	E'ly	/			/	
*8-1	70	4/18/16	V. Lt. Var'ble	SW'ly.		/			/
8-2	70	4/24/16	N'ly.	SE'ly.	/			/	
8	70	4/22/16	SE'ly.	SW'ly	/				/
8	70	1/8/17	N'ly.	E'ly.		/		/	
8	70	3/19/17	"	NE'ly.		/		/	
*8	70	3/30/17	Lt. E'ly	E'ly.			/	/	
8	70	4/24/17	W'ly.	SE'ly.	/			/	
8	70	8/13/17	"	"	/			/	
9	80	4/11/16	"	E'ly.	/			/	
9	80	4/24/16	N'ly	SE'ly.	/			/	
9	80	4/24/16	"	E'ly.		/		/	
9	80	1/8/17	"	"		/		/	
9	80	3/19/17	"	NE'ly.			/	/	
*9	80	3/30/17	Lt. E'ly	E'ly.			/	/	
9	80	4/24/17	W'ly.	SE'ly.	/			/	
9	80	8/13/17	"	"	/			/	
10	90	4/11/16	"	E'ly	/			/	
10	90	4/24/16	N'ly.	SE'ly.	/			/	
10	50	4/24/16	"	E'ly.		/		/	
10	90	1/18/17	"	"		/		/	
10	90	3/19/17	"	"		/		/	
*10	90	3/30/17	Lt. E'ly.	"			/	/	
10	90	4/24/17	W'ly.	SE'ly.	/			/	
10	90	8/13/17	"	"	/			/	
12	20	4/17/16	Lt. NE'ly.	SW'ly.	/				/
*12	20	4/25/16	Lt. N'ly.	"		/			/
12	18	1/25/17	NE'ly.	"	/				/
12	15	3/19/17	N'ly.	W'ly.		/			/
*12	18	3/30/17	Lt. E'ly.	SW'ly.			/	/	
12	15	4/25/17	Lt. W'ly	"	/			/	
12	18	8/4/17	W'ly	S'ly.	/			/	
13	30	4/12/16	N'ly	S'ly.	/			/	
*13	30	4/17/16	Lt. Var'ble	S.W'ly.		/		/	
13	30	4/21/16	SE'ly.	W'ly.	/				/
13	30	11/13/16	NE'ly.	"	/				/
13	30	2/10/17	N'ly.	SW'ly	/			/	
13	30	4/7/17	W'ly.	S'ly	/			/	
13	30	4/24/17	"	"	/			/	
13	30	8/14/17	"	SE'ly.	/			/	
14	40	4/12/16	N'ly.	S'ly.	/			/	
*14	40	4/17/16	Lt Var'ble	SW'ly		/		/	
14	40	4/21/16	SE'ly	W'ly	/				/
14	40	11/13/16	NE'ly.	"	/				/
14	40	2/10/17	N'ly.	S.W'ly.	/			/	
14	40	4/7/17	W'ly.	S'ly	/			/	
14	40	4/24/17	"	"	/			/	
14	40	8/14/17	"	"	/			/	
15	15	1/19/17	NE'ly.	W'ly.	/				/
15	15	2/10/17	N'ly.	SW'ly.	/			/	
*15	15	3/30/17	Lt E'ly.	"		/		/	
15	15	4/26/17	Lt W'ly.	"	/			/	
15	15	8/11/17	W'ly.	"		/			/
16	18	11/13/16	NE'ly.	"	/				/
16	18	2/10/17	N'ly	"	/			/	
*16	18	3/30/17	Lt E'ly.	"		/			/
16	15	4/26/17	Lt. W'ly.	"	/			/	
16	18	8/11/17	W'ly	"		/			/
17	15	1/19/17	NE'ly.	W'ly	/				/
*17	15	2/9/17	Var'ble	S'ly		/		/	
17	15	3/30/17	Lt E'ly	SW'ly	/				/
17	15	4/26/17	Lt W'ly.	"	/			/	
17	15	8/11/17	W'ly	"		/			/
18	15	1/19/17	NE'ly.	W'ly	/				/
*18	15	2/9/17	Var'ble	SE'ly.		/		/	
18	15	3/30/17	Lt. E'ly.	SW'ly.	/				/
18	15	4/26/17	Lt. W'ly.	S'ly	/			/	
18	15	8/11/17	W'ly.	SW'ly.		/			/
				TOTALS	91	20	1	71	41
% OF TOTAL NO. OF OBS'NS.					81.3	17.8	0.9	63.4	36.6

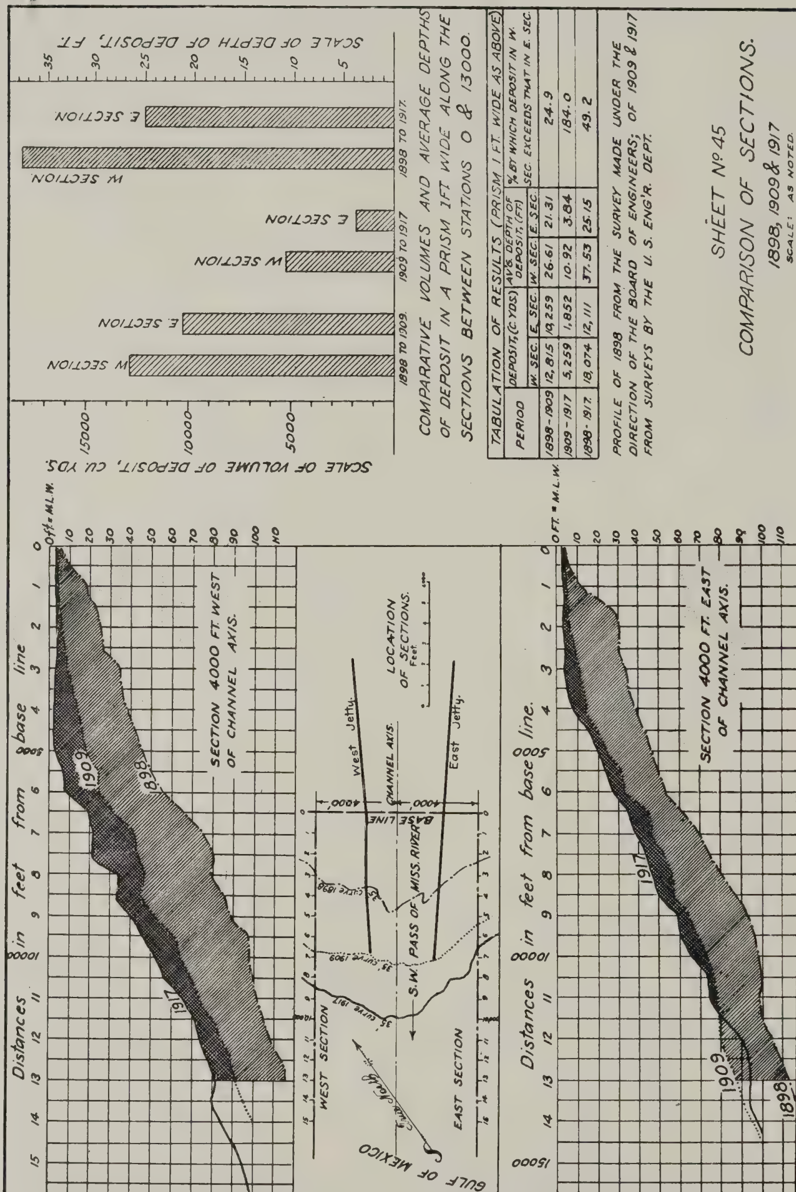
† Movement of upper 20 ft stratum of water as indicated by drift of Dredge "New Orleans"

‡ Movement of upper 10 ft stratum of water as indicated by drift of tug "C. Donovan."

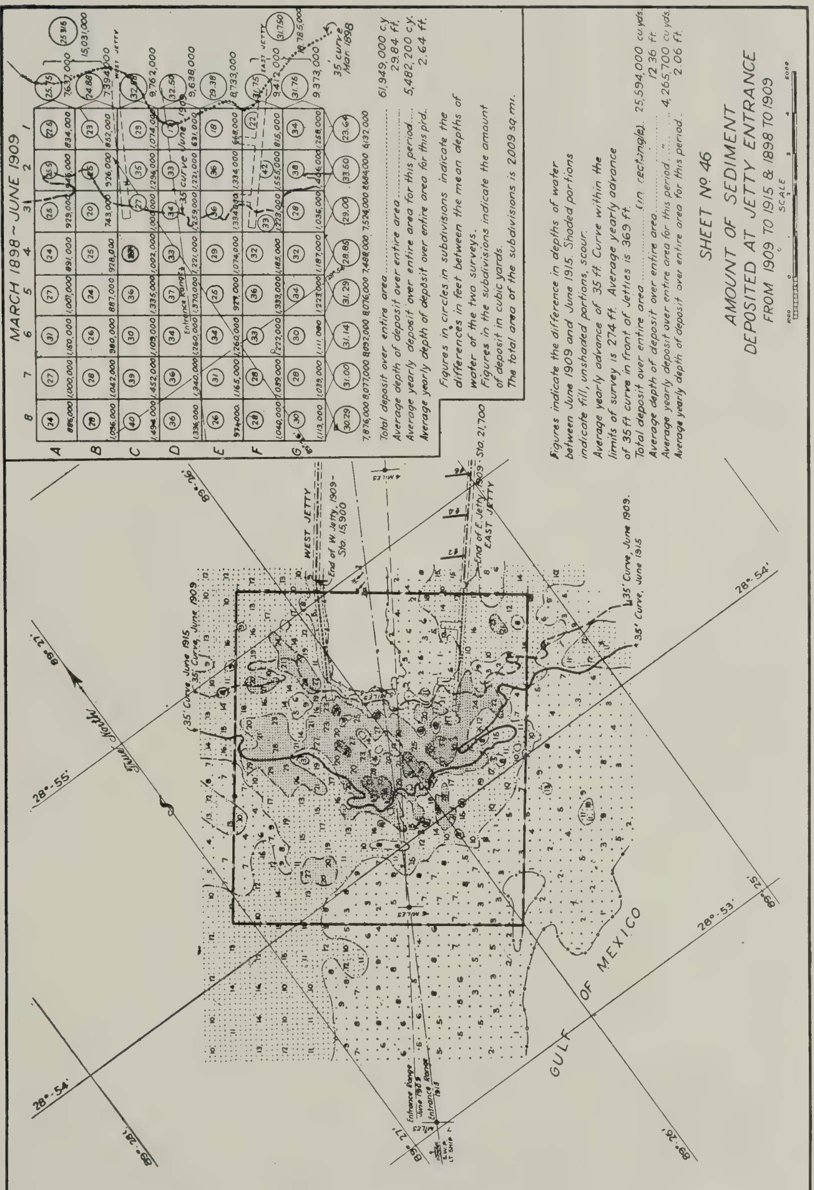
* Not included in totals as wind for 3 days prior to obs'n. was light or variable making the relation between the dir'n. of this wind and that of the current impossible of satisfactory interpretation.

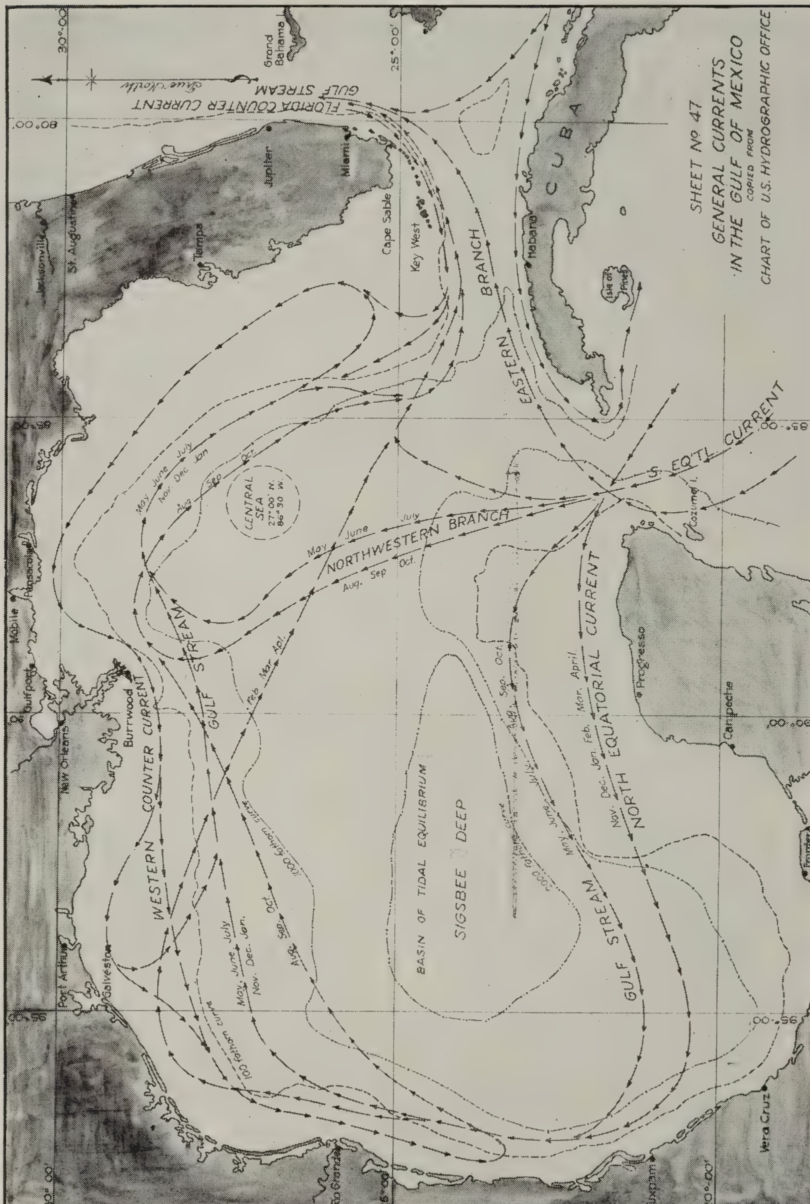
Easterly or Westerly current as noted in the last 2 columns refers to a direction to the east or west of the jetty axis & on % of the direction of this axis will not always be in the true E or W semi-circle, but as indicated in sketch above.

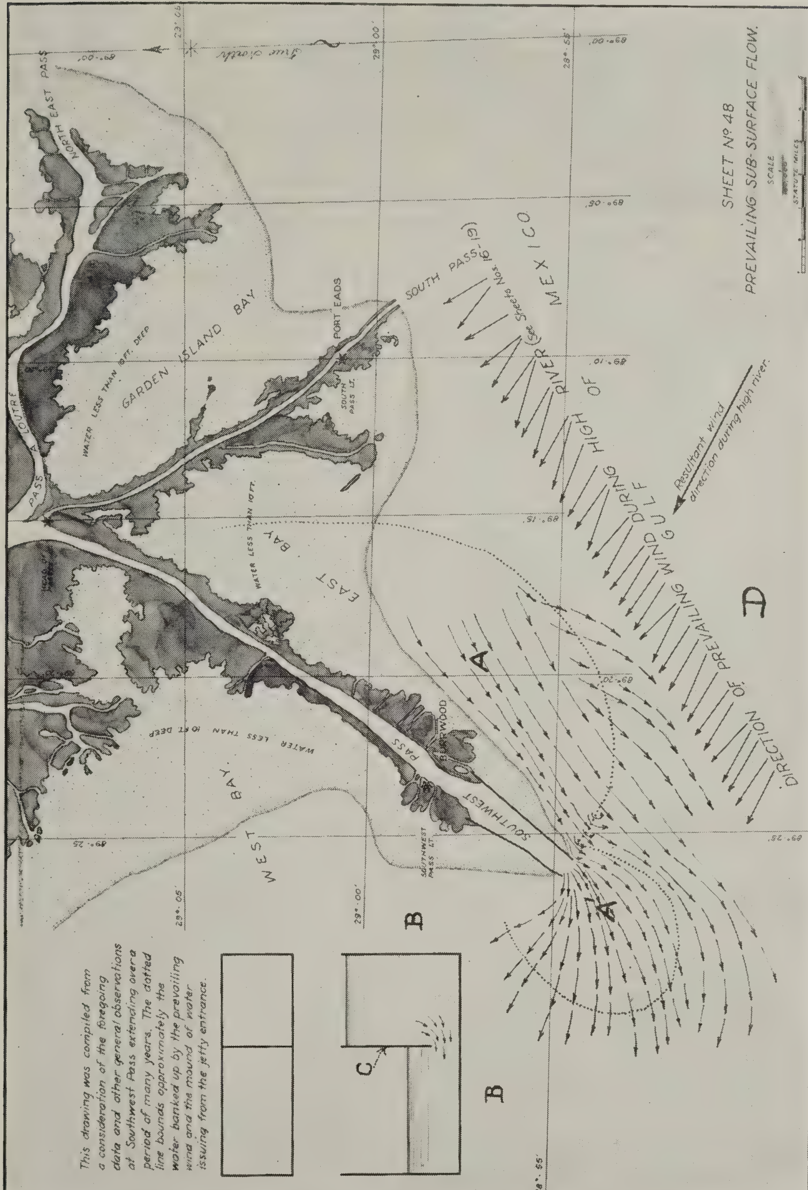
SHEET Nº 44
SUBSURFACE CURRENTS
TABULATION OF RESULTS.



PERIOD	DEPOSIT, (C. YDS.)		AV'G. DEPTH OF DEPOSIT, (FT.)		% BY WHICH DEPOSIT IN W. SEC. EXCEEDS THAT IN E. SEC.
	W. SEC.	E. SEC.	W. SEC.	E. SEC.	
1898-1909	12,815	10,259	26.61	21.31	24.9
1909-1917	5,259	1,852	10.92	3.84	184.0
1898-1917	18,074	12,111	37.53	25.15	49.2


MARCH 1898 ~ JUNE 1909
Total deposit over entire area 61,949,000 c.y.
Average depth of deposit over entire area 29.84 ft.
Average yearly deposit over entire area for this period 5,482,200 c.y.
Average yearly depth of deposit over entire area for this prd. 2.64 ft.
Figures in circles in subdivisions indicate the differences in feet between the mean depths of water of the two surveys.
Figures in the subdivisions indicate the amount of deposit in cubic yards.
The total area of the subdivisions is 2.009 sq.mi.
Figures indicate the difference in depths of water between June 1909 and June 1915. Shaded portions indicate fill, unshaded portions, scour.
Average yearly advance of 35 ft. Curve within the limits of survey is 274 ft. Average yearly advance of 35 ft curve in front of Jetties is 369 ft.
Total deposit over entire area (in rectangle) 25,594,000 cu.yds.
Average depth of deposit over entire area 12.36 ft.
Average yearly deposit over entire area for this period 4,265,700 cu.yds.
Average yearly depth of deposit over entire area for this period 2.06 ft.
SHEET No 46
AMOUNT OF SEDIMENT
DEPOSITED AT JETTY ENTRANCE
FROM 1909 TO 1915 & 1898 TO 1909
SCALE
WEST JETTY
End of W. Jetty, 1909 - Sta. 15,900
EAST JETTY
End of E. Jetty, 1909 - Sta. 21,700
35' Curve, June 1909
35' Curve, June 1915
True North
GULF OF MEXICO
28°-55'
28°-54'
28°-53'


SHEET Nº 47
GENERAL CURRENTS
IN THE GULF OF MEXICO
COPIED FROM
CHART OF U.S. HYDROGRAPHIC OFFICE
GULF STREAM
FLORIDA COUNTER CURRENT
EASTERN BRANCH
NORTHWESTERN BRANCH
S. EQ'TL CURRENT
NORTH EQUATORIAL CURRENT
GULF STREAM
WESTERN COUNTER CURRENT
CENTRAL SEA
BASIN OF TIDAL EQUILIBRIUM
SIGSBEE DEEP
CUBA
Habana
Isle of Pines
Key West
Cape Sable
Miami
Jupiter
Tampa
St. Augustine
Jacksonville
Pensacola
Mobile
Gulfport
New Orleans
Burrwood
Port Arthur
Galveston
Rio Grande
Tuxpam
Vera Cruz
Frontera
Campeche
Progresso
Cozumel I.
Grand Bahama I.


SHEET No. 48
PREVAILING SUB-SURFACE FLOW.
This drawing was compiled from a consideration of the foregoing data and other general observations at Southwest Pass extending over a period of many years. The dotted line bounds approximately the water banked up by the prevailing wind and the mound of water issuing from the jetty entrance.
GULF OF MEXICO
DIRECTION OF PREVAILING WIND DURING HIGH RIVER (See Sheets Nos. 16, 19)
Resultant wind direction during high river.
GARDEN ISLAND BAY
EAST BAY
WEST BAY
WATER LESS THAN 10 FT. DEEP
PASS A LOUTRE
NORTH EAST PASS
SOUTH PASS
PORT EADS
SOUTH PASS LT.
SOUTHWEST PASS
SOUTHWEST PASS LT.
BURRWOOD
True North
SCALE
STATUTE MILES
A
B
C
D
29° 05'
29° 00'
28° 55'
89° 00'
89° 05'
89° 10'
89° 15'
89° 20'
89° 25'

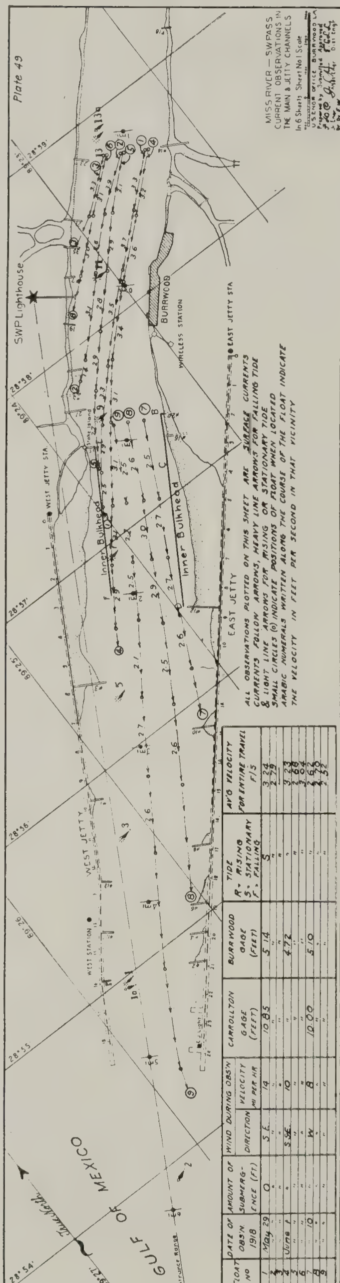


Plate 49
MISS RIVER — SWPASS
CURRENT OBSERVATIONS IN
THE MAIN & JETTY CHANNELS
In 6 Sheets Sheet No 1 Scale
SWP Lighthouse
BURRWOOD
WIRELESS STATION
EAST JETTY STA
WEST JETTY STA.
Inner Bulkhead
Inner Bulkhead
EAST JETTY
WEST JETTY
WEST STATION
GULF OF MEXICO
Entrance Range
ALL OBSERVATIONS PLOTTED ON THIS SHEET ARE SURFACE CURRENTS
CURRENTS FOLLOW ARROWS, HEAVY LINE ARROWS FOR FALLING TIDE
& LIGHT LINE ARROWS FOR RISING OR STATIONARY TIDE
SMALL CIRCLES (o) INDICATE POSITIONS OF FLOAT WHEN LOCATED
ARABIC NUMERALS WRITTEN ALONG THE COURSE OF THE FLOAT INDICATE
THE VELOCITY IN FEET PER SECOND IN THAT VICINITY
FLOAT NO
DATE OF OBS'N 1918
AMOUNT OF SUBMERGENCE (FT.)
WIND DURING OBS'N
DIRECTION
VELOCITY MI PER HR
CARROLLTON GAGE (FEET)
BURRWOOD GAGE (FEET)
TIDE R = RISING S = STATIONARY F = FALLING
AV'G VELOCITY FOR ENTIRE TRAVEL F/S

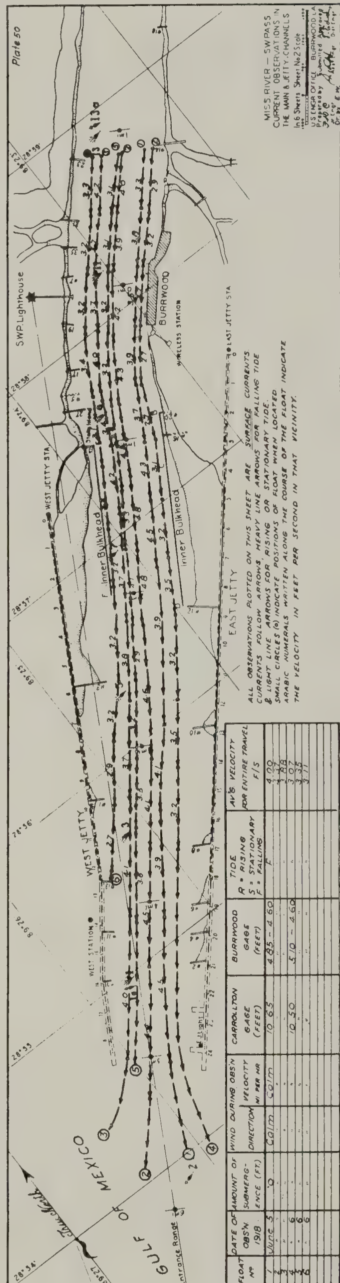


Plate 50
MISS RIVER — SWPASS
CURRENT OBSERVATIONS IN
THE MAIN & JETTY CHANNELS
In 6 Sheets Sheet No 2 Scale
SWP Lighthouse
BURRWOOD
WIRELESS STATION
EAST JETTY STA
WEST JETTY STA.
Inner Bulkhead
Inner Bulkhead
EAST JETTY
WEST JETTY
WEST STATION
GULF OF MEXICO
Entrance Range
ALL OBSERVATIONS PLOTTED ON THIS SHEET ARE SURFACE CURRENTS
CURRENTS FOLLOW ARROWS, HEAVY LINE ARROWS FOR FALLING TIDE
& LIGHT LINE ARROWS FOR RISING OR STATIONARY TIDE.
SMALL CIRCLES (o) INDICATE POSITIONS OF FLOAT WHEN LOCATED
ARABIC NUMERALS WRITTEN ALONG THE COURSE OF THE FLOAT INDICATE
THE VELOCITY IN FEET PER SECOND IN THAT VICINITY.
FLOAT No
DATE OF OBS'N 1918
AMOUNT OF SUBMERGENCE (FT.)
WIND DURING OBS'N
DIRECTION
VELOCITY MI PER HR
CARROLLTON GAGE (FEET)
BURRWOOD GAGE (FEET)
TIDE R = RISING S = STATIONARY F = FALLING
AV'G VELOCITY FOR ENTIRE TRAVEL F/S

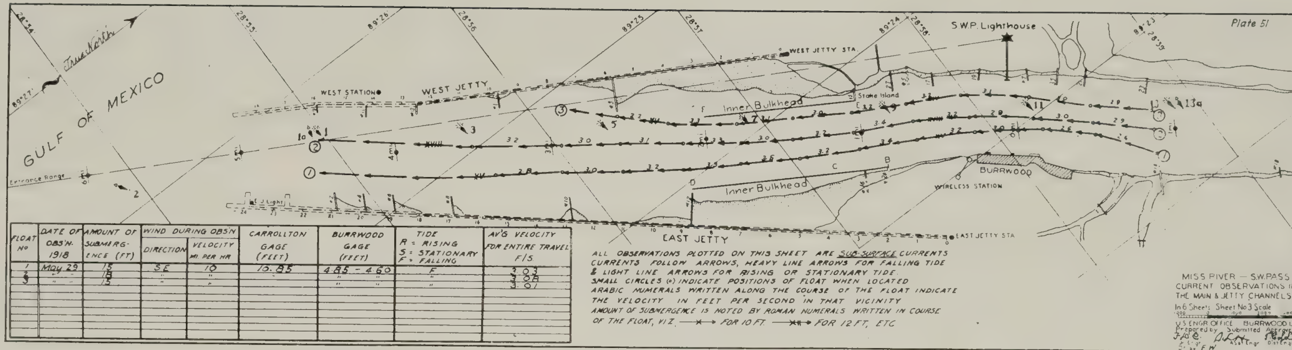


Plate 51
S.W.P. Lighthouse
WEST JETTY STA.
WEST STATION
WEST JETTY
GULF OF MEXICO
True North
Entrance Range
Stake Island
Inner Bulkhead
Inner Bulkhead
BURRWOOD
WIRELESS STATION
EAST JETTY
EAST JETTY STA.
FLOAT No | DATE OF OBS'N. 1918 | AMOUNT OF SUBMERGENCE (FT) | WIND DURING OBS'N DIRECTION | VELOCITY MI PER HR | CARROLLTON GAGE (FEET) | BURRWOOD GAGE (FEET) | TIDE R = RISING S = STATIONARY F = FALLING | AV'G VELOCITY FOR ENTIRE TRAVEL F/S
1 | May 29 | 15 | SE | 10 | 15.85 | 4.85 - 4.60 | F | 3.03
2 | " | 18 | " | " | " | " | " | 3.08
3 | " | 12 | " | " | " | " | " | 3.01
ALL OBSERVATIONS PLOTTED ON THIS SHEET ARE SUB-SURFACE CURRENTS
CURRENTS FOLLOW ARROWS, HEAVY LINE ARROWS FOR FALLING TIDE
& LIGHT LINE ARROWS FOR RISING OR STATIONARY TIDE.
SMALL CIRCLES (o) INDICATE POSITIONS OF FLOAT WHEN LOCATED
ARABIC NUMERALS WRITTEN ALONG THE COURSE OF THE FLOAT INDICATE
THE VELOCITY IN FEET PER SECOND IN THAT VICINITY
AMOUNT OF SUBMERGENCE IS NOTED BY ROMAN NUMERALS WRITTEN IN COURSE
OF THE FLOAT, VIZ. FOR 10 FT. FOR 12 FT, ETC
MISS RIVER — S.W.PASS
CURRENT OBSERVATIONS IN
THE MAIN & JETTY CHANNELS
In 6 Sheets Sheet No 3 Scale
U.S. ENGR OFFICE BURRWOOD LA
Prepared by Submitted Approved

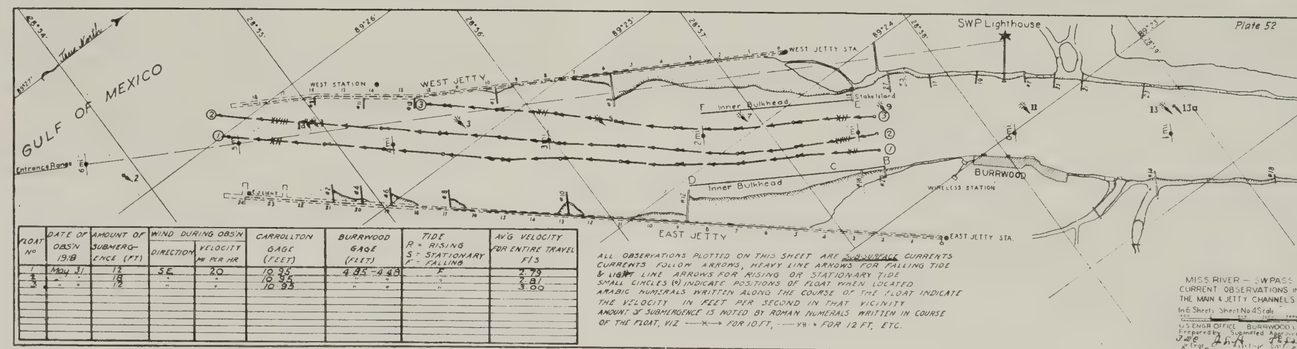


Plate 52
SWP Lighthouse
WEST JETTY STA.
WEST STATION
WEST JETTY
GULF OF MEXICO
True North
Entrance Range
Stake Island
Inner Bulkhead
Inner Bulkhead
BURRWOOD
WIRELESS STATION
EAST JETTY
EAST JETTY STA.
FLOAT No | DATE OF OBS'N 1918 | AMOUNT OF SUBMERGENCE (FT) | WIND DURING OBS'N DIRECTION | VELOCITY MI PER HR | CARROLLTON GAGE (FEET) | BURRWOOD GAGE (FEET) | TIDE R = RISING S = STATIONARY F = FALLING | AV'G VELOCITY FOR ENTIRE TRAVEL F/S
1 | May 31 | 12 | SE | 20 | 10.95 | 4.85 - 4.48 | F | 2.79
2 | " | 18 | " | " | 10.95 | " | " | 2.81
3 | " | 12 | " | " | 10.95 | " | " | 3.00
ALL OBSERVATIONS PLOTTED ON THIS SHEET ARE SUB-SURFACE CURRENTS
CURRENTS FOLLOW ARROWS, HEAVY LINE ARROWS FOR FALLING TIDE
& LIGHT LINE ARROWS FOR RISING OR STATIONARY TIDE
SMALL CIRCLES (o) INDICATE POSITIONS OF FLOAT WHEN LOCATED
ARABIC NUMERALS WRITTEN ALONG THE COURSE OF THE FLOAT INDICATE
THE VELOCITY IN FEET PER SECOND IN THAT VICINITY
AMOUNT OF SUBMERGENCE IS NOTED BY ROMAN NUMERALS WRITTEN IN COURSE
OF THE FLOAT, VIZ FOR 10 FT, FOR 12 FT, ETC.
MISS RIVER — S.W.PASS
CURRENT OBSERVATIONS IN
THE MAIN & JETTY CHANNELS
In 6 Sheets Sheet No 4 Scale
U.S. ENGR OFFICE BURRWOOD LA
Prepared by Submitted Approved

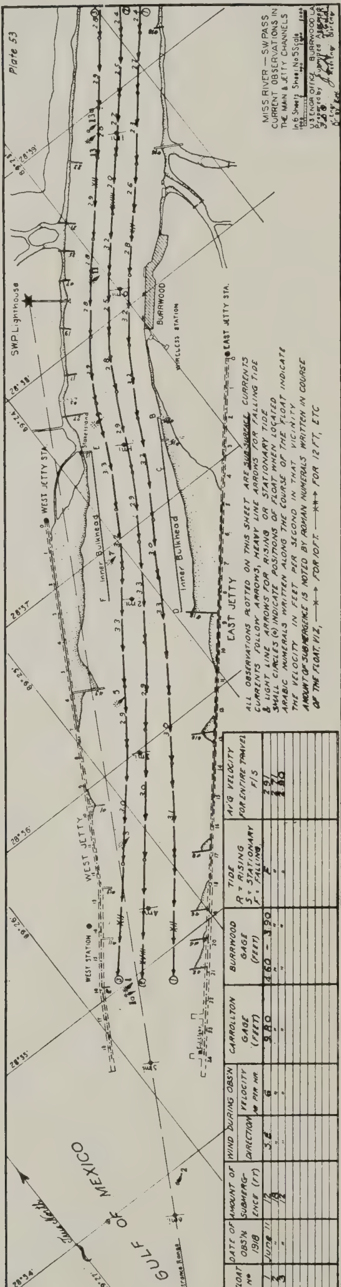


Plate 53
MISS RIVER — SW PASS
CURRENT OBSERVATIONS IN
THE MAIN & JETTY CHANNELS
GULF OF MEXICO
WEST JETTY
EAST JETTY
SWP Lighthouse
BURRWOOD
Inner Bulkhead
WEST JETTY STA.
EAST JETTY STA.
WEST STATION
WIRELESS STATION
ALL OBSERVATIONS PLOTTED ON THIS SHEET ARE SUB-SURFACE CURRENTS

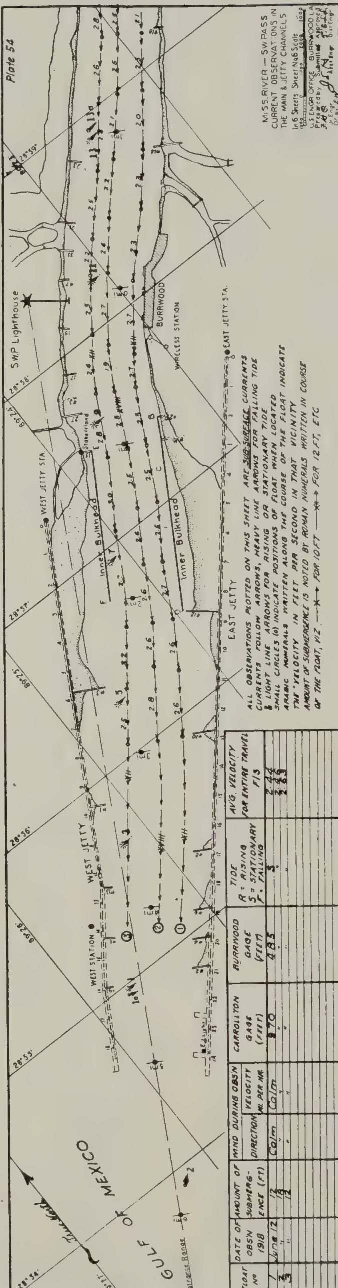


Plate 54
MISS RIVER — SW PASS
CURRENT OBSERVATIONS IN
THE MAIN & JETTY CHANNELS
GULF OF MEXICO
WEST JETTY
EAST JETTY
SWP Lighthouse
BURRWOOD
Inner Bulkhead
WEST JETTY STA.
EAST JETTY STA.
WEST STATION
WIRELESS STATION
ALL OBSERVATIONS PLOTTED ON THIS SHEET ARE SUB-SURFACE CURRENTS

JARED MANSFIELD.

By

Col. W. R. Livermore,
Corps of Engineers; ret.

Among those whose names which will long be associated with the development of our great western country, that of Jared Mansfield is well worthy of distinction. Sprung from an old New England family, he was born in New Haven, Conn., on the 23d of May, 1759, and graduated at Yale College in 1777.

Soon after, he taught school in New Haven and afterwards at the Friends' Academy in Philadelphia, paying special attention to mathematics. Among his pupils at New Haven were the two Baldwin brothers; one of whom became a United States senator from Georgia, and the other a Judge of the Supreme Court of the United States. In 1802 Mansfield published a series of Essays Mathematical and Physical, in which he called attention to the fact that while Americans had shown great talent in literature, they had neglected mathematical studies which, in our growing country, would be most useful and most practical, and which had been developed so wonderfully abroad. In one of the Essays, he explained the principles of the new mathematics, in others its application to navigation, surveying, and other practical work. The Baldwin brothers were very proud of their old teacher's work, and brought it to the attention of President Jefferson, who was deeply interested in the progress of Science. The Military Academy at West Point was then organizing, and Mansfield was appointed Acting Professor of Mathematics and Captain in the Corps of Engineers.

In May, 1803, the President, in a private letter, wrote to Captain Mansfield offering him the position of Surveyor General, in which he pointed out the defects in the surveys of public lands then existing and said: "We have been wanting . . . also, accurate determinations by astronomical observation of several points and lines in our geography very interesting to us." By an Act of Congress in 1785, the land ceded to the United States, including

lands to which the Indian title had been or would be extinguished, were ordered to be surveyed and divided "into townships of six miles square, by lines running due north and south, and others crossing these at right angles as near as may be," etc. In 1796 these surveys were placed in charge of an officer called "The Surveyor General of the Northwest Territory."

The law did not require the determination of the latitude and longitude of the base lines of the principal meridians. The work had been vigorously conducted under Gen. Rufus Putnam, who with all his accomplishments was not an educated mathematician, and as the work progressed it was impossible to co-ordinate the surveys, which were not as accurate as they should have been. Captain Mansfield was appointed with the understanding, afterwards confirmed, that he should receive the pay of Surveyor General, and hold his rank without pay and receive due promotion in the Corps of Engineers, and that proper astronomical instruments should be furnished him for fixing points of latitude and longitude and locating meridian lines astronomically. President Jefferson ordered the proper instruments (at a cost of $1,054) from London. Mansfield removed to Ohio and established an astronomical observatory at his own house at Cincinnati, which was at least one of the first in America. The instruments reached him there and were used in making many astronomical observations ordered by the Government. They are now on deposit in the Deposit in the Department of Philosophy at West Point. Mansfield was promoted to Major of Engineers June 1, 1805, Lieutenant Colonel, February 25, 1808. On the 23rd of July, 1810, he resigned his commission in the army.

The report upon United States Surveyor west of the One Hundredth Meridian in charge of Captain Wheeler, Vol. I, p. 407, says: "Captain Jared Mansfield, U. S. Army, filled this office [Surveyor General] from 1803 to 1813. Under him, many and important changes and improvements were made in the surveying system which had been adopted in 1785. These changes and improvements were the introduction of greater accuracy, and the determination of the principal lines by astronomical observations.

The Land Service Bulletin, Department of the Interior, General Land Office for April 1, 1918, gives a concise account of the Rectangular System of Surveying, of which it says: "It is only by careful review of the whole record that we are forced to the inevitable conclusion that the perfected system is not the creation of any

one man, but of a number of men throughout the course of many years, and like all great inventions born of Necessity has been like her children reared in the slow but thorough process of evolution to full growth and perfection. . . . Jared Mansfield was selected by President Jefferson to succeed Putnam in 1803 as Surveyor General of the United States and to him must always belong the credit of having not only introduced a refinement of scientific method to public land surveying as it had never known before, but of placing the System beyond the possibility of failure. He was a man of recognized scientific attainment, of sound judgment, tact and energy, an excellent administrative officer, forceful and just in dealing with the many sided problems confronting his field parties in the Western country and thoroughly absorbed in his work. He furthermore enjoyed the full confidence of President Jefferson, who took a keen interest in and gave unstinted encouragement to him in his work. . . . Mansfield's part in the development of the Rectangular System was the introduction of primary control in the form of Base Line and Principal meridians, and the establishment of these lines in accordance with scientific principles. They constituted the frame-work around which the structure—townships—was built; up to this time what should have been created first had been created last and the fact of its creation at all is Mansfield's achievement. . . . Thus was accomplished one more great step which permanently assured the future success of the Rectangular System of Surveying."

Captain Wheeler's report says: "The Dominion of Canada, after examination and comparison of all known methods of land parceling, has based its subdivisions upon the system originally introduced in the United States and carried out very much in the same manner as was intended by Captain Mansfield that the surveys of the United States should have been prosecuted, who may be termed the founder of the rectangular system, geographically disposed and checked."

On the 7th of October, 1812, he was appointed Professor in the new Department of Philosophy in the Military Academy at West Point. He did not enter upon his duties until April 10, 1814.

The regulations approved July 2, 1816, by Secretary of War Crawford, provided for "philosophy; embracing mechanics, hydraulics, pneumatics, optics, chemistry, magnetism, and astronomy."

Up to the summer of 1817 the instruction in philosophy was of the most elementary character, "not a few graduates leaving the Academy without having had any instruction whatever therein. The only apparatus in the professor's possession to illustrate his subject were a field transit and a clock."

In the fall of 1818 a treatise on mechanics, by Dr. Olinthus Gregory, of the Royal Military Academy, Woolwich, was introduced and taught to the first section of the class. It was apparently too difficult for the second section.

On the 29th of January, 1820, the Academic Board adopted a definite course in Philosophy including Statics, Dynamics, Hydrostatics, Hydrodynamics and Hydraulics, Pneumatics, Machinery, Optics, Astronomy (descriptive and physical), Practical Astronomy.

The account of the West Point Centennial Celebration says: "Professor Mansfield was much beloved and respected by the Cadets and deemed an efficient instructor. He was extremely near-sighted and of such a delicate structure as to convey the idea of decrepitude. His manner was very gentle, and as a professor he was by no means rigid. As an astronomical observer he was quite renowned."

Mansfield was not a genius but he was a vigorous, earnest and patient scholar and teacher who helped to direct the education of America into those channels where it could develop the strength of the nation. After struggling with the primæval forests and the Indians on one side, and the Teutonic despot on the other, Americans had given some attention to literature, but as a rule had not made equal progress along the path that Franklin had opened up in the field of exact and physical science, which, of all subjects, were then required for the great work of developing the vast regions that had fallen to them. Mansfield's early teachings and writings helped the young to realize the value of the mathematical and physical discoveries of the great thinkers of the old world in developing the resources of the new. His field work helped so to organize the great region that the public domain could be placed at the disposal of the earnest men and women who were pouring into it. His work in Mathematics and Physics, in each of which he was the first to hold the chair at the Military Academy, laid the foundation for that exact and thorough study and teaching of exact science which enabled its graduates to perform their varied

duties and placed at the disposal of the government a corps of men upon whom they could rely to solve the knotty problems as they arose, and to organize new departments and new technical schools until the methods, born at the departments of Mathematics and Philosophy at West Point, contributed to give to the growing country that character which has placed it in the high position it now holds in the family of nations.

Use of Pack Mules for Carrying Rock.[1]

It was not possible to use wagons on the road for transporting rock, due to the fact that there was but one track and it was not considered advisable at that time to construct a turn road for the empty wagons, which were unable to return over the crowded trail. The pack mules were found to be a great help. The boxes which had been made for transporting rock on pack mules were soon discarded, it being considered that the time lost in filling the boxes and sandbags filled with rock were substituted for the boxes.

The method is highly recommended for use on all congested highways when the road must be completed under the wheels of moving vehicles. It is believed that the 24 mules used on the job transported more rock than was transported by 300 of the Pioneer Infantry. Each mule carried a load of 4 sandbags full of rock. Bags of rock were placed on the upper rail and slung with a lyer rope only. Mules worked individually with one man to lead them, and moved in and out and about traffic, and were easily loaded and unloaded.

[[1]Extract from the report of operations of the 602d Engineers.]

NOTES ON THE OPERATIONS OF THE ITALIAN ENGINEERS.[1]

By

Lieut. James H. England,

Engineers, U. S. Army.

WATERWAYS.

The war brought to Italy a realization of the wonderful possibilities in the navigation of inland waterways. As these had been neglected and allowed to run down during peace times, considerable work was required to place them in usable form. The results, however, fully justified the labor involved. Not only was heavy and bulky freight carried with efficiency but, what was more important, great relief was afforded to the congestion in other modes of transportation.

Beginning with the few canals in use at the outbreak of the war, the system has rapidly grown until there are now over 1,300 kilometers of canals bearing an almost endless stream of traffic. First the old abandoned canals were made serviceable, then new ones were dug and short connecting branches thrown out. Hastily built wooden locks were installed in order to expedite the opening of the system. Hand in hand with the construction of the canals proper went the building of tow-paths and landing places. The latter were then connected with some main highway or railroad. All of this work as well as the building of scows and canal boats was under military control.

There are at present about 450 boats in use, the average carrying capacity being 1,400 quintals.[2] These boats are moved either by horses which are unfit for army duty or by power boats. There are some 50 of the latter, ranging in capacity from 25 to 350 horsepower. From August, 1915, to April, 1917, there were carried on waterways about 4,500,000 quintals of freight. The major portion

[1]The data and photographs from which this article was prepared were very kindly furnished by Capt. G. Bevione and Lieut. D. A. Costantini of the Italian War Mission to the United States.

[2]A quintal is equivalent to 220 pounds.

Fig. 1. Common type of road.

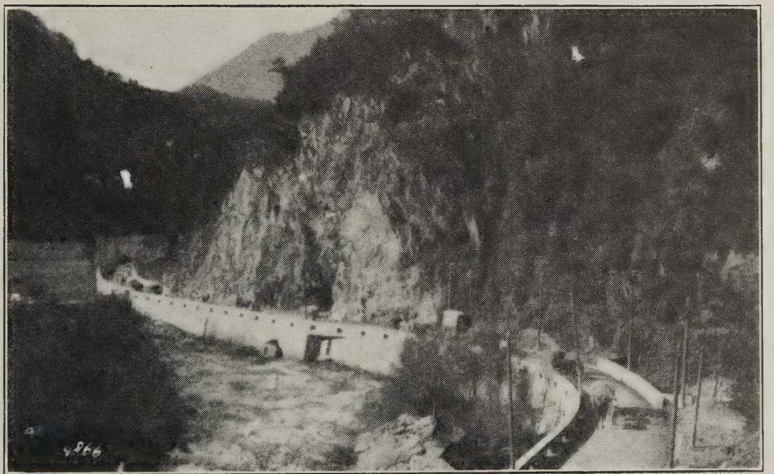


Fig. 2. Permanent highway.

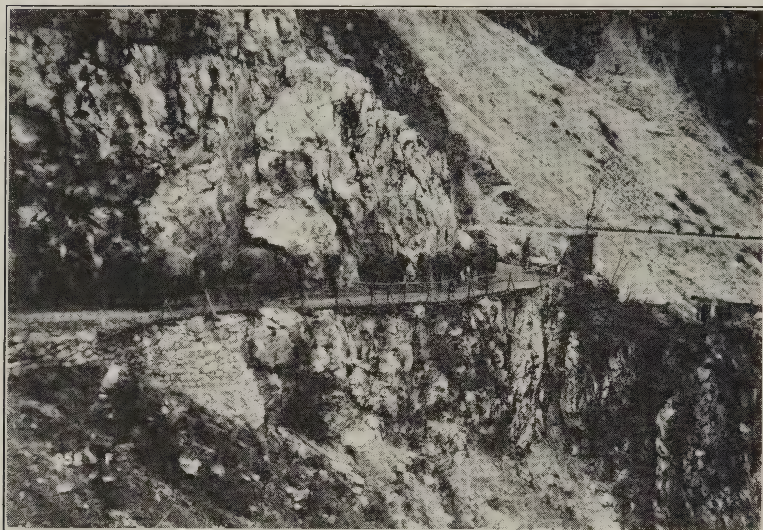


Fig. 3. Road built along rocky face of mountain.

Fig. 4. Road becomes narrower as it approaches its terminus.

of this consisted of road material—sand, gravel, etc.—bulky construction material, and wheat, oats and other grains.

ROADS.

The road system of the Italians has often been favorably commented upon by visiting Allied officers. It is no more than to be expected that the best in road building should be found here, for it was from the Roman Empire that the world learned how to build good roads. The military roads of Rome extended some 53,000 miles (Roman) of which 9,000 miles were in Italy. Several splendid examples remain—the Postumia from Genoa to Aquileia, one in the Julian Alps, and four in the Rhætian Alps. Renowned in ancient times for serviceable military highways, Italy has upheld her reputation by the well-planned, sturdily built and efficiently maintained roads which have spread like a net-work over her front.

Conditions under which these roads have been planned and built differ widely. Some connect important distribution points and carry enormous traffic; others wind slowly and tortuously to the highest peaks, and the traffic consists solely of those few things needed at this one commanding point. Always there is the controlling element of time and in many instances the best road is a very rudely built one just good enough to sustain the immediate and pressing traffic needs.

In general, the roads are designed and constructed with a view to accommodating the 10-ton power truck. The width is regulated by the importance of the route and the estimated amount of traffic. Where a width much less than 15 feet is necessary, frequent recesses are provided in order that the trucks may pass each other. The limiting grade is about 8 per cent and the maximum curvature is governed solely by the ability of the power trucks to make the turn.

The need of speed in this work makes it necessary very often to build a road along a route surveyed by no other instrument than a military engineer's skilled eye. That these roads have admirably served the purpose is but another testimonial to the experience and training of the Italian engineer.

The types of construction are the ones most frequently used in times of peace. There are a few asphaltic or bituminous concrete, more of concrete but in the main water-bound macadam is the material employed. Of course there are also many miles of

ordinary roads with no other surface than spread gravel or earth. In very few instances have so-called corduroy roads been built. It is interesting to note that no attempt has been made to use the large flat stones so much in vogue in the ancient days.

The usual type of macadam road is shown in Fig. 1. It will be noted that it has been built from the rock excavated along its route. A splendid bit of highway coustruction is seen in Fig. 2. In this instance a very substantial and permanent piece of road has been built for the reason that none other would have been

Fig. 5. Trench mortar squad moving into action along footroad.

able to withstand the effects of the mountain torrent along which it runs.

Fig. 3 gives a fairly good idea of some of the unusual conditions under which roads have been built through the mountains. Attention is directed to the fact that even in places of this nature the road has been built to fit the traffic and that there is ample room to allow two streams of traffic, moving in opposite directions, to pass. As the objective is neared these roads become narrower. Fig. 4 shows this condition. Here only one stream of traffic can move at one time. Another example of this narrowing is the footroad in Fig. 5, along which a trench mortar squad is moving up to its position. The use of a built-up rock embankment makes

the space normally occupied by one road serve for two. The upper road is reached by a flight of stone steps at the turn.

Advantage has been taken of the most modern machinery in building the roads. It was not advisable to use rock crushers, due to the loss of time in transporting and erecting them. Civilian labor was used freely to prepare the rock—men, women and children being employed. All other operations were performed by such machinery as steam and compressed-air rock drills, mechanical tampers, steam shovels and excavators, steam rollers, etc.

(Notes on Aerial Cableways, Hydroelectrical Development, Tunneling and Mining, etc , will be published in an early issue.)

AMMUNITION DUMPS.[1]

In connection with the work done by this Regiment in building artillery ammunition dumps, some explanations may be of interest and possible value.

The length, approximately 400 meters, was thought necessary to localize an explosion and the distance between the 60 centimeters and the plank roads was established at about 50 feet as being a distance not too great to carry and pile ammunition and to keep the necessary clearing as conspicuous.

This regiment did nothing in the way of laying out locations for the various sizes of ammunition, merely hinging to the site duckboards on which the ammunition could be piled.

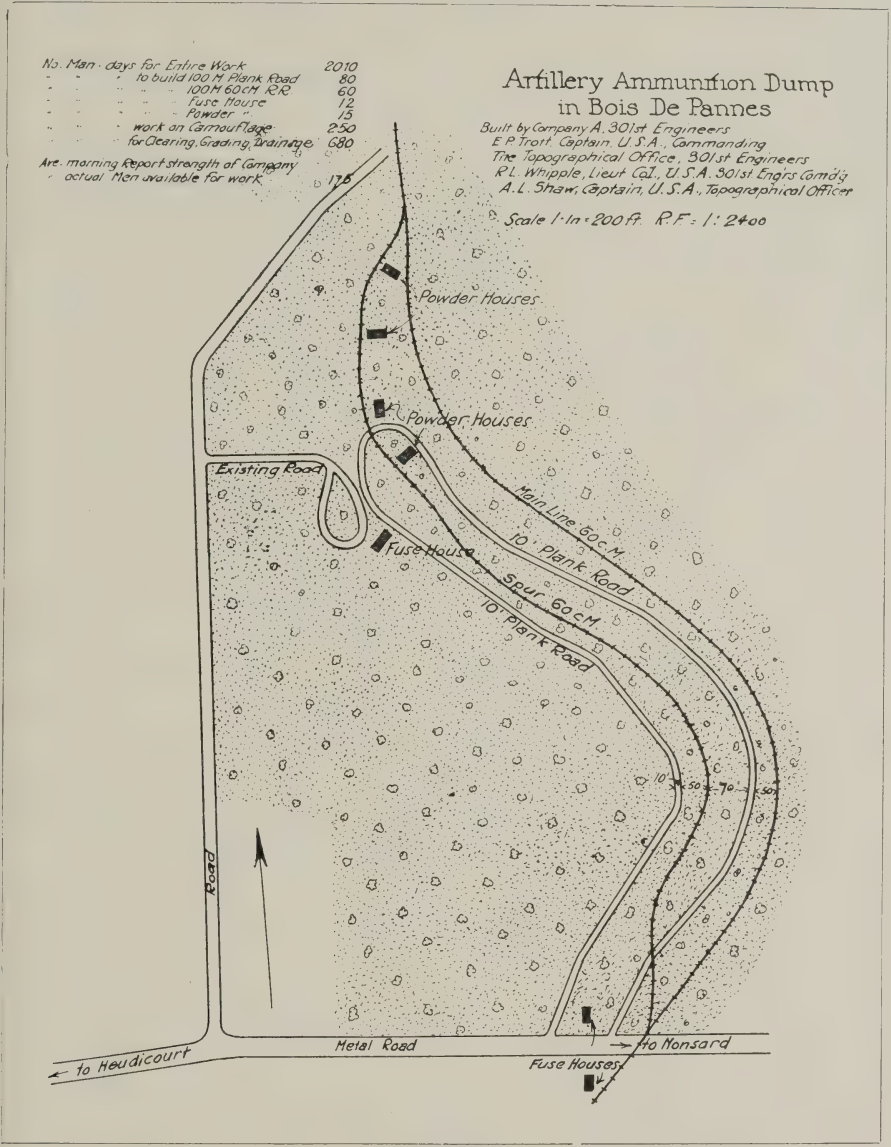
The powder and fuse houses are of course widely separated. It appears to be good practice to keep fixed ammunition by itself. The powder and fuse houses are merely light framed structures roofed and sided with corrugated iron with a floor of duckboards or rough plank, high enough to be dry.

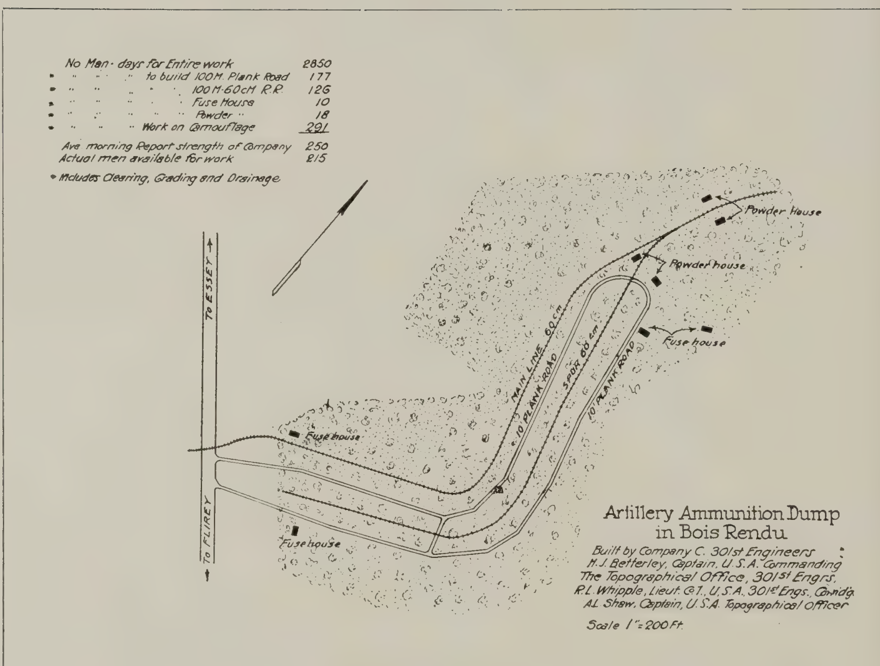
The concealment of a dump of this design can be done very effectively if it is not necessary to build approaches through open ground, as was the case at the Flirey Dump. The minimum amount of cutting of brush and trees should be done and all large trees should be left intact. Wherever practicable the branches should be arched over the road and 60 centimeters Deconville and tied together with wire. Where this can not be done, the conventional types of flat top camouflage should be used.

At the Flirey Dump an attempt was made to camouflage the plank roads running in and out of the woods, and for this two separate screens were erected. Aerial photographs made it perfectly evident that this is a waste of time and material. One large screen covering both the entrance and exit might have been useful.

The prints will give some data concerning the amount of labor, in man-days, required to build this type of ammunition dump. The conditions under which the work was done might be said to be average conditions in the field, but a great deal of time was wasted through lack of materials.

[1]An appendix to the report of operations of the 301st Engineers.


No. Man-days for Entire Work 2010
" " " to build 100 M Plank Road 80
" " " " " 100 M 60 cM R.R. 60
" " " " " Fuse House 12
" " " " " Powder " 15
" " " work on Camouflage 250
" " " for Clearing, Grading, Drainage 680
Are. morning Report strength of Company
" actual Men available for work 175
Artillery Ammunition Dump
in Bois De Pannes
Built by Company A, 301st Engineers
E. P. Trott, Captain, U.S.A., Commanding
The Topographical Office, 301st Engineers
R. L. Whipple, Lieut Col., U.S.A. 301st Eng'rs Comd'g
A. L. Shaw, Captain, U.S.A., Topographical Officer
Scale 1 In = 200 ft. R.F. = 1 : 2400
Powder Houses
Powder Houses
Existing Road
Fuse House
Main Line 60 cM
10' Plank Road
Spur 60 cM
10' Plank Road
10'
50
70
50
Road
Metal Road
to Heudicourt
to Nonsard
Fuse Houses


No Man-days for Entire work 2850
* " " " to build 100M. Plank Road 177
* " " " " 100 M-60cM R.R. 126
* " " " " Fuse House 10
* " " " " Powder " 18
* " " " Work on Camouflage 291
Ave. morning Report strength of Company 250
Actual men available for work 215
* Includes Clearing, Grading and Drainage
To ESSEY
To FLIREY
Powder House
Powder house
Fuse house
Fuse house
Fuse house
MAIN LINE 60 cm
10' PLANK ROAD
SPUR 60 cm
10' PLANK ROAD
Artillery Ammunition Dump
in Bois Rendu
Built by Company C. 301st Engineers
H. J. Betterley, Captain, U.S.A. Commanding
The Topographical Office, 301st Engrs.
R. L. Whipple, Lieut. Col., U.S.A., 301st Engs., Comdg.
A. L. Shaw, Captain, U.S.A. Topographical Officer
Scale 1" = 200 Ft.

A Letter from Gen. John J. Pershing and Reply of Gen. W. C. Langfitt.

The following letter from General Pershing, with reference to the work of the Engineers during the present war, and the reply of General Langfitt, have been transmitted by the Chief of Engineers for publication in PROFESSIONAL MEMOIRS.

AMERICAN EXPEDITIONARY FORCES,
HEADQUARTERS SERVICES OF SUPPLY,
OFFICE OF THE CHIEF ENGINEER, A. E. F.

25 February, 1919.

The following letters are forwarded for your information. It is requested that you communicate same to your command.

Major General WM. C. LANGFITT,
Chief Engineer, A. E. F.

My Dear General Langfitt:

As the activities of our army in France draw to a close, I desire to express to you, and through you to the officers, enlisted men and civilian personnel of the Engineer Department, my appreciation of their loyal and energetic work, which contributed so greatly to our success.

The various units attached to combat troops distinguished themselves at all times in the assistance which they rendered. The Division of Construction and Forestry, with limited resources at its disposal and under conditions of extreme severity, more than met the many demands made upon it. The Department of Light Railways and Roads furnished the indispensable link between the railheads and the front lines for the transportation of troops and supplies, and for the evacuation of sick and wounded. Its record in the construction and operation of light railways and roads has seldom been equalled.

The many other services of the Engineer Department, connected with the acquisition and distribution of engineer supplies, particularly those needed for combat operations, were so conducted that our forces never lacked for any essential.

The Engineer Department has made a proud record for itself, and it gives me pleasure to express to you my sincere thanks and admiration, and that of your comrades of the American Expeditionary Forces, for its splendid achievements.

Sincerely yours,

(Signed) JOHN J. PERSHING.

General JOHN J. PERSHING,
Commander-in-Chief
American Expeditionary Forces.

My Dear General Pershing:

Not only on my behalf but on behalf of all the Engineers who have served under your leadership in France, permit me to express my deep appreciation of the sentiments of your letter of February 20th.

The knowledge that the Engineers have to so great an extent earned your good will and commendation is the highest possible reward that could have come to officers and men alike. Without these their services in France would have been to no purpose.

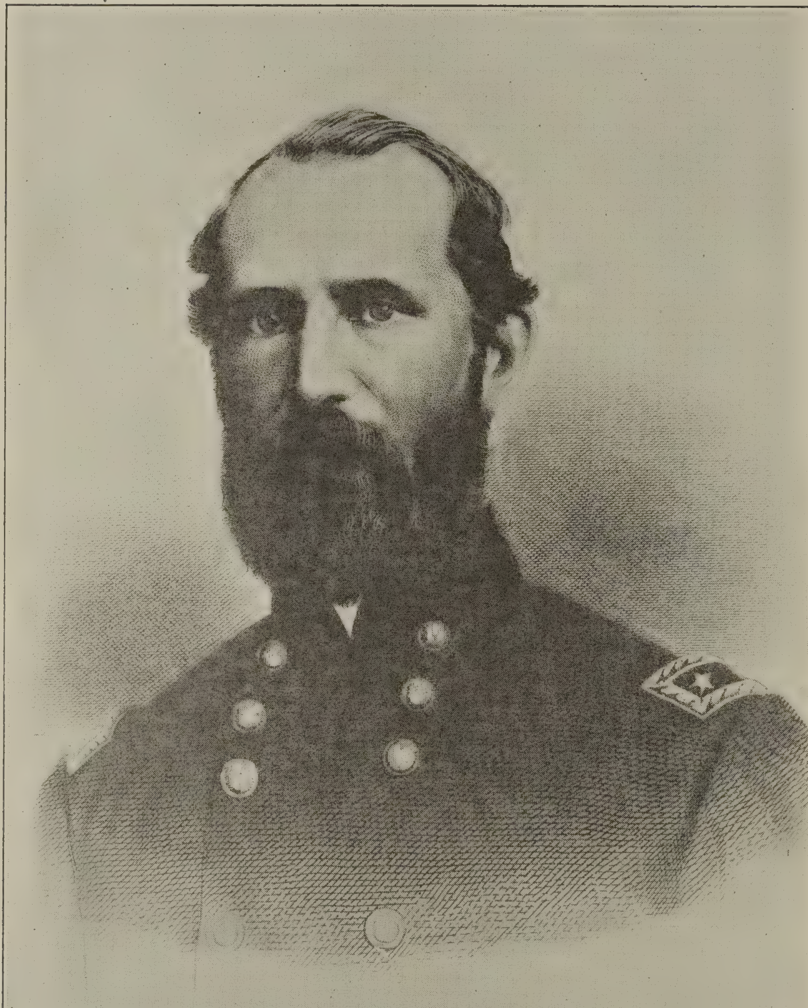
It will give me keen satisfaction to communicate the contents of your letter to the organizations and individuals concerned, so that they may be stimulated to continue their efforts to merit your approval.

With renewed expressions of the desire of every Engineer in France to give his utmost service to you in your great work, believe me,

Cordially yours,

(Signed) W. C. LANGFITT,
Major General, U. S. A.

Official:
E. A. KANE,
Captain, Engineers,
Adjutant.



MAJOR GENERAL JOHN GRAY FOSTER
1823-1874

THE DEVELOPMENT OF ANTI-AIRCRAFT SEARCHLIGHTS[1]

By

Lieut. Col. James B. Cress,
Engineers, U. S. Army.

Prior to our entry into the war against Germany, searchlight development had been for two purposes: (1) Seacoast Defense; (2) Battlefield Illumination.

For seacoast defense, 36-inch and 60-inch lights had been adopted. These had reached a high efficiency. They were fitted with distant control mechanisms, were provided with an excellent generating system and were giving good service. Steps had been taken to replace the medium intensity arcs by the latest development in searchlights, the high intensity arc. These lights, however, since they were designed for permanent emplacement on seacoast fortifications and for distant control, were heavy, of complex construction and costly.

The development of searchlights for battlefield illumination was taken up in 1907 and carried on until the outbreak of the war. Lack of funds, however, made it necessary to restrict developments. Nevertheless, a number of foreign types were studied, and several designs prepared in the United States were manufactured and tested. During June of 1916, four horse-drawn 36-inch searchlight outfits were ordered, and, soon after, eight automobile tower sets. The latter each consisted of a 36-inch searchlight on a Strauss extension tower, mounted on one F. W. D. truck, and of a motor generator set mounted on a second F. W. D. truck. These sets were similar to outfits manufactured for the Russian government. When tested they showed certain disadvantages, notably their weight and lack of mobility.

Shortly before the United States entered the War, eighty-five 24-inch searchlight sets were ordered. These were of the horse-drawn, limber and caisson type, very similar to sets which had been

[1]The responsibility for the selection and development of engineer equipment has been recently assigned to the Equipment Section of the Troop Division in the Office of the Chief of Engineers.

manufactured for the German government. While not perfect, they were the best all-round field searchlights available. The limber carried the motor generator set and the caisson, an extension mast supporting a 24-inch high intensity searchlight. At the time the United States entered the War, the Strauss outfits had been delivered and eighty-five 24-inch and four 36-inch horse-drawn sets were in the process of manufacture.

Through reports received during the fall of 1917 from American officers in France, it was first learned that ''field searchlights'' were no longer used on the battlefield, but that enemy bombing operations were becoming so extensive that some form of anti-aircraft searchlight defense was essential. For this defense, highly portable lights which could be given elevation of 90° were necessary. The problem resolved itself into two parts: (1) That of providing a portable power unit; (2) That of providing a portable searchlight capable of 90° elevation.

To meet immediate needs, forty 4-ton Riker trucks were shipped to France, where they were converted into power units by placing an electric generator in front of the engine to which it was connected by a flexible coupling. The design of a similar power unit was taken up in the United States and put into production. In this design, a generator was placed in front of the engine of a 5½-ton Mack truck. Later, a more mobile power unit was developed from a standard Cadillac chassis. On this machine a generator was placed around the shaft, approximately under the front seat. The unit developed about 20 K. W. cost less than the Mack power unit, could travel at a greater speed, and because of its lightness traverse roads impassable for a heavier machine. Like the Mack unit, it carried a searchlight in the body of the truck. It had the disadvantage, however, that it did not have as great a capacity for transporting the supplies and personnel necessary for operating the light, as had the heavier units. There is now being built a La France equipment, which is expected to develop sufficient power to run a high ampere arc, and have sufficient capacity to carry all necessary personnel and equipment. In addition, work is in progress in the development of improved searchlights for seacoast duty.

The first step in the development of a light-weight searchlight was the manufacture of a sample similar to the standard 36-inch in which parts were made as light as practicable, and from which were eliminated all appliances necessary for distant control and all parts which could be classed as non-essential. This light was

Fig. 1. One of the eight Strauss tower lights ordered during the summer of 1916 (36-inch light).

mounted on a carriage made up of a steel frame supported on standard Ford axles and wheels. The light could be turned through 360° in azimuth and 220° in elevation. Including carriage, it weighed 1,200 pounds as against 4,000 pounds of the standard 36-inch seacoast searchlight. Prior to the completion of this sample, however, and in order not to delay production, a large order was placed for 36-inch lights constructed similar to the one here mentioned, but with a greater factor of safety. These lights, including carriage, weighed 1,600 pounds. The success of the 1,200-pound 36-inch light led to another step in the development, the construction of a 60-inch light, along similar lines. When built, it weighed 1,800 pounds, and was, up to that time, the lightest searchlight of its size.

While the searchlights mentioned above were under construction, an experimental detachment had been organized and field tests started. In addition, the large manufacturers of electrical equipment, numerous scientific bodies, and noted scientists, were called upon to assist in improving the searchlight and its power unit. At one time, besides the development detachment, some fifty-five firms, scientific bodies and scientists were working on searchlight problems. The thorough manner in which the study of the searchlight was carried on is one of the most interesting features of its development. No stone was left unturned which might disclose a possibility, or further the improvements desired. At one time, as many as one hundred and sixty-two problems were under investigation.

During the spring of 1918, it was suggested that a searchlight could be built without the front glass, which was found to absorb about 25 per cent of the light. After careful consideration, the first Dishpan searchlight was manufactured. This light, as shown by the illustration, is composed essentially of the mirror, the mirror support and the mechanism. With its carriage, the latest 60-inch light of this type weighs about 900 pounds and gives a more powerful and effective light than an inclosed searchlight using the same mechanism, current and mirror. Compared to the 60-inch seacoast light in use at the beginning of the war, it costs about one-fourth as much, weighs about one-eighth as much and is more powerful.

One of the interesting subsidiary developments connected with the general improvement of the searchlight is that of the *mirror.* At the outbreak of the war, only one firm in the United States man-

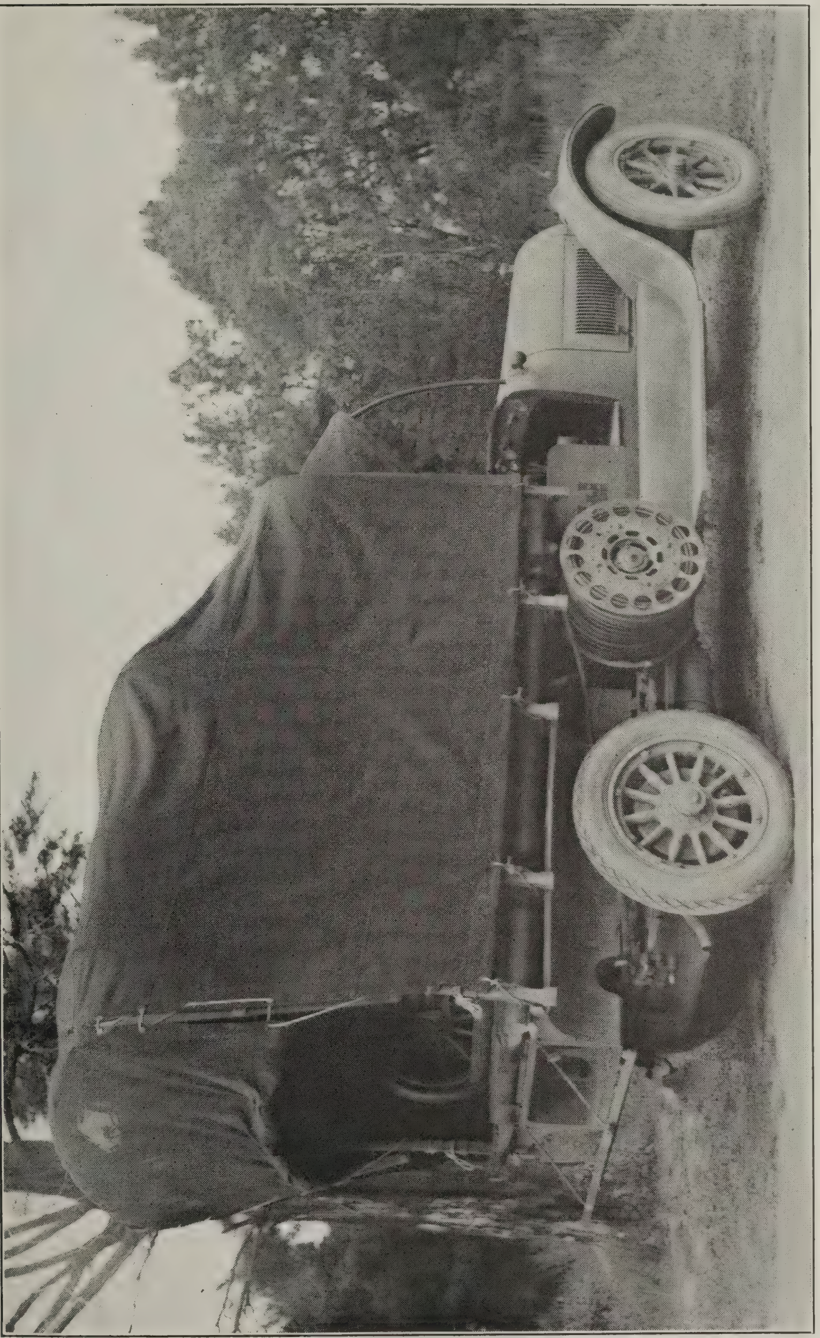


Fig. 4. "Cadillac" Power Unit carrying a 60-inch Dishpan Searchlight.

ufactured glass mirrors, and their output was limited to approximately one mirror per week. Further, to obtain optical glass in the United States was almost impossible. Before the war closed, three firms could be counted on to produce glass mirrors; but, more important still, a type of mirror had been sufficiently developed for war purposes which could be turned out in almost unlimited quantities and at a cost of about one-third that of the glass mirror. This was a metal mirror. While the final design of these mirrors has not yet been determined, it is certain that they can be effectively used in place of glass, and that they have many advantages over the glass mirror. They will not shatter if struck by a projectile or shell fragment; as mentioned above, they can be manufactured in quantity far surpassing that of the glass type, and much more economically; but perhaps more interesting still is the fact that they permit of a higher development of the searchlight than was heretofore considered possible. Because a glass mirror absorbs about 8 per cent of all the incident light, and because of the poor conductivity of glass, mirrors made from it become hot, and, in practice, have usually cracked when used with arcs carrying more than 200 amperes. The metal mirror, however, runs cold with these powerful arcs. This quality, when considered with the efficiency of the metal mirror, which the latest tests have shown to be from 95 to 99 per cent of that of the best glass mirrors, is alone almost enough to warrant its adoption to replace the glass mirror.

The development of *carbons* has also advanced very rapidly. Before the war, carbons for high intensity lights—that is, for lights which use an incandescent carbon gas as their illuminating source, all came from abroad. Now carbons which cost less than those previously considered standard and which give more than three times as much light are being produced in this country.

Distant controls for searchlights have been carefully investigated and several manufacturers have submitted promising samples.

The development of *mechanisms* for the searchlight has made possible the use of a much higher current density, which produces a more intense light with either a longer range or a greater field. The medium intensity light—that is, one in which incandescent carbon forms the source of light, as well as the high intensity light in which incandescent carbon vapors form the source of light, have been carefully investigated. Both medium and high intensity lights taking as much as 500 amperes have given satisfactory tests.

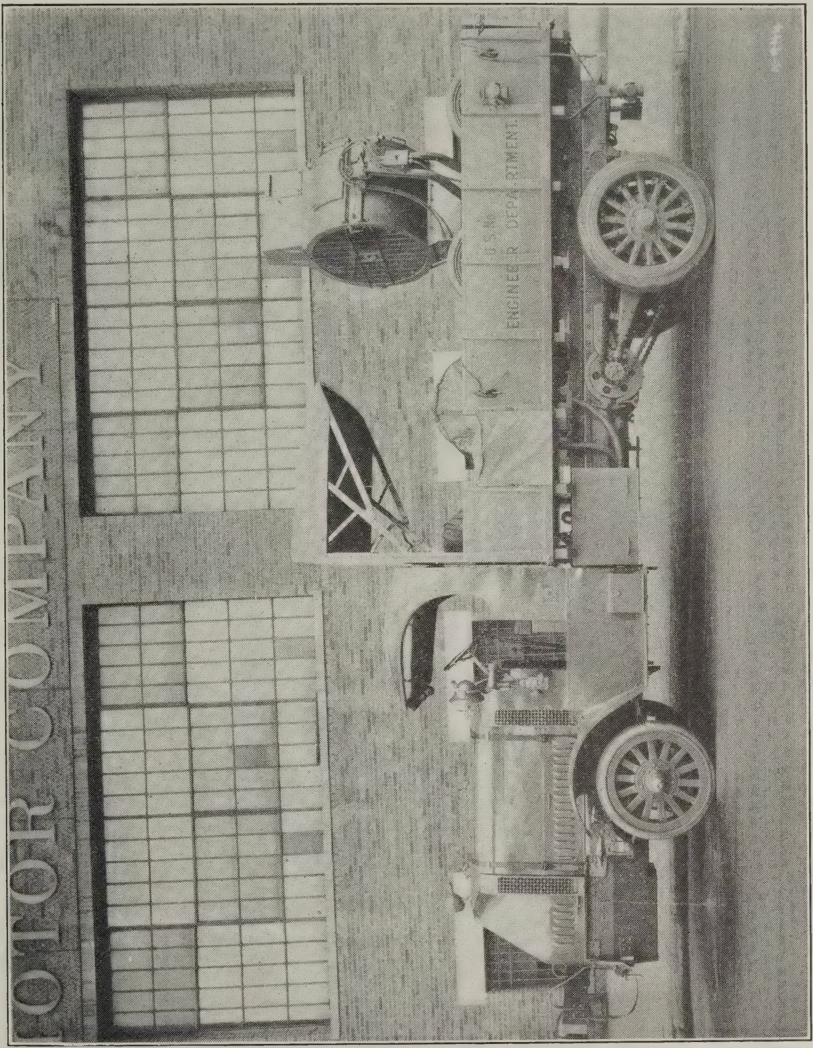


Fig. 3. "Mack" Power Unit carrying a 36-inch Searchlight.

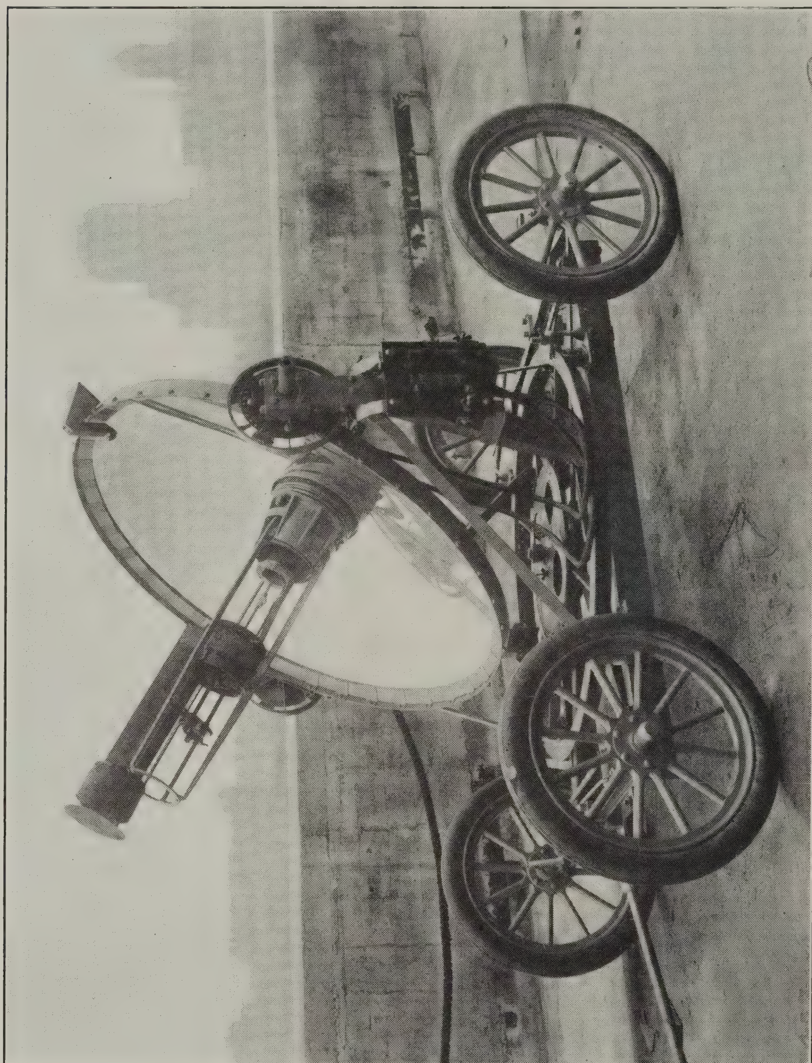


Fig. 6. One of the 60-inch Dishpan Searchlights.

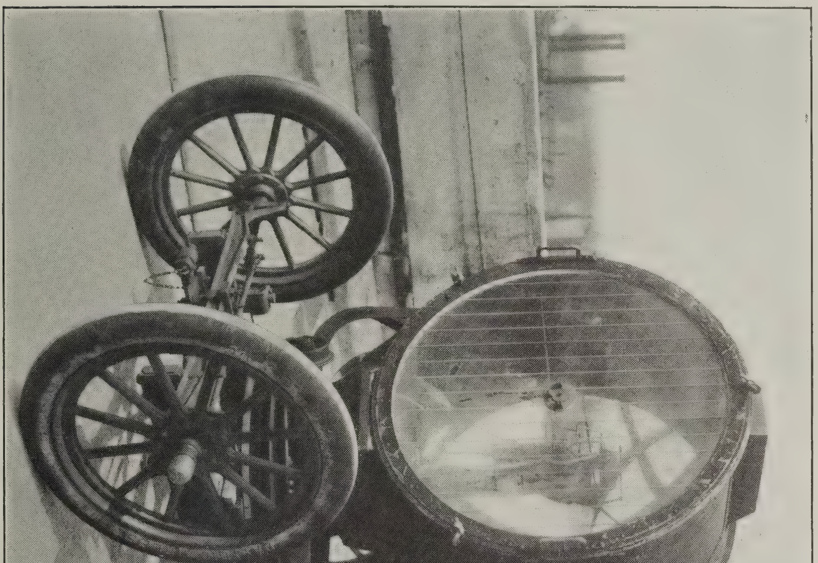


Fig. 5. The first light-weight 36-inch Searchlight.

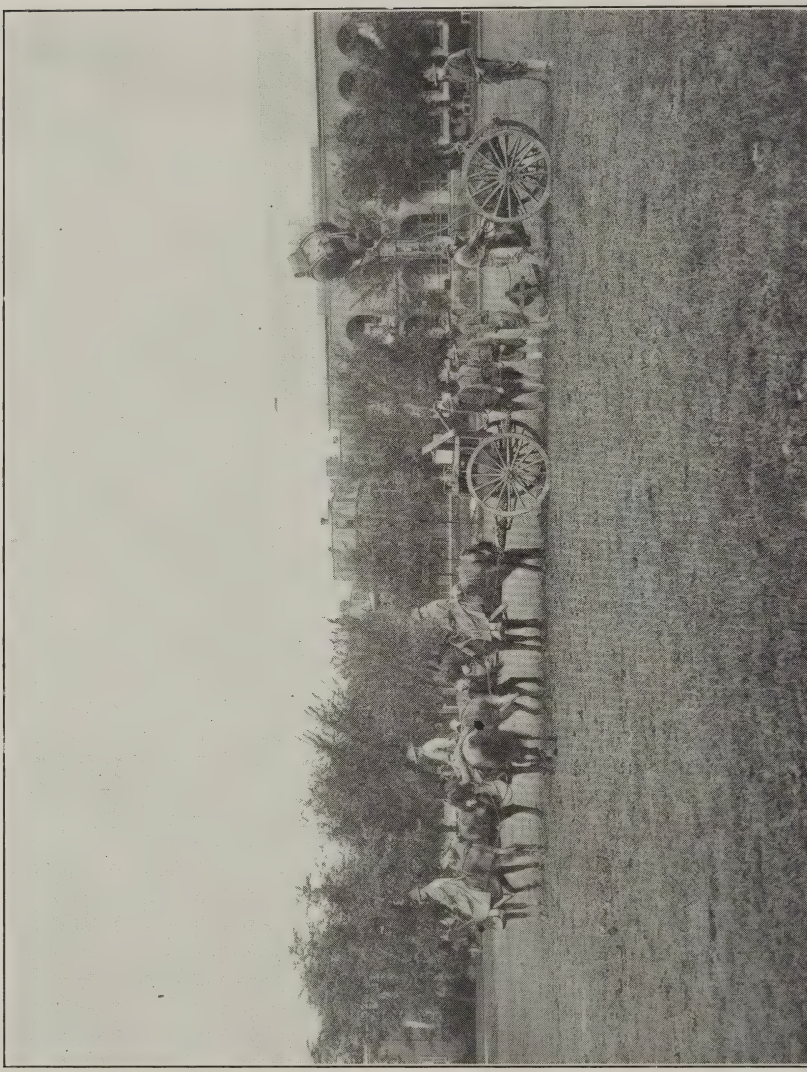


Fig. 2. 24-inch Limber and Caisson set—one of the eighty-five ordered shortly before the outbreak of war.

Whether the blue light produced by the high intensity arc, or the yellow light produced by the medium intensity arc, is better for picking up aeroplanes, will soon be carefully studied.

What the light of the future will be is problematical. Definite reports as to requirements are now coming back from Europe. From a study of these and of the material available, it is believed that it will soon be possible to decide upon the best unit or types of units. After this, the great essential of searchlight work will be *training*.

Certain it is that, in future wars, we must expect, not less activity from night bombers, but, on the contrary, more. To prevent this bombing, we must rely upon close cooperation between efficient searchlights and squadrons of pursuit aeroplanes.

TECHNICAL ENGINEERING DETAILS OF THE HINDENBURG LINE IN THE SECTOR OF ATTACK OF THE II ARMY CORPS.

By

Col. G. B. Pillsbury,
Engineers, U. S. A.
Deputy Chief Engineer, A. E. F.

The sector assigned to the II Corps in the attack on the Hindenburg line on September 29, 1918, embraced a front of about 6,000 yards. To the north and south of the sector, the defense rested on the line of the St. Quentin Canal, but in the sector itself the canal passed through a deep tunnel, from 100 to 200 feet under ground, depriving the defense of this obstacle. The terrain is characterized by rolling hills, of some elevation but with gentle slopes; and bare of trees. The trend of the ridges is generally parallel to the defense line in the southern half of the sector, and oblique in the northern half. The defense line runs through the small village of Bony, and immediately in front of the town of Bellicourt. Both of these places have been reduced to ruins under long continued artillery fire. The soil of the region is chalk, naturally quite pervious but quickly kneaded into a greasy clay underfoot. It is easily excavated. Ground water is from 100 to 200 feet below the ground surface.

The data for this report was secured from a reconnaissance of the canal tunnel and of the defense, made by a party of the 105th Engineers in November, 1918; and on two days' examination made by the writer in January, 1919.

It will be recollected that the Hindenburg line, on this front, was deliberately prepared for resistance. It partakes of the nature of a semi-permanent line of fortifications, rather than of a field work. In all the works constructed by the opposing forces during the long years of trench warfare, this line of defense stands out as incomparably the most elaborate and thorough. A study of the line, and particularly of the effect of artillery on the structures pertaining to it is, therefore, of much interest to the military engineer.

In considering the effect of artillery fire, it must be borne in mind that the defenses were not subjected to any such wholesale artillery preparation as has been sometimes practiced. It was considered that this preparation was unnecessary, and events justified the wisdom of the decision.

The defenses of the Hindenburg line proper, in this sector, are formed of two or three lines of trenches, provided with underground dugouts and concrete shelters, machine-gun emplacements, and observation posts. The wire entanglement is exceptionally extensive and of exceptional density. In front of the line at a distance of from 1,500 to 2,000 yards there is an outpost position, a portion of which, however, was in our hands before the attack begun.

TRENCHES.

The distance between the successive lines of trenches varies from 150 to 300 yards. The connecting communication trenches are at intervals of from 100 to 400 yards; there being one about every 300 yards on the average. Normally the system has two lines of trenches only, but the village of Bony was organized as a strongpoint with a salient third line, and an advanced third line was also constructed in front of Bellicourt. The latter, nearly 3,500 yards in length, was apparently constructed subsequently to the main system, and was much lighter in character, as noted hereafter. The rear trench of the system was almost everywhere on a reverse slope; the front trench, often in rear of the crest, commanded obliquely the forward slopes, but often had a very limited frontal field of fire.

The profile of the trenches varied considerably. Apparently the time and labor had not been found to fully complete the whole system according to plan. Where complete the profile was that shown in Fig. 1. As a rule the trenches were wholly unrevetted, but in the vicinity of Bony the fire step of the front line trench had a board revetment, held in place by stakes wired to anchors in the parapet. Much of the trench was short of the dimensions shown in Fig. 1, but all of the parallels were a good 5 feet deep, and wide enough to stand without revetment. The normal section of the front line in front of Bellicourt, for example, is shown in Fig. 2. There were but few sections where the fire step was in such condition that it could be manned. On long stretches there was no fire step at all. The whole scheme of defense appeared to rest on machine-gun fire.

The traverses of the main trench lines were about 7 yards in thickness and 7 yards in depth at parapet level. In the advanced line in front of Bellicourt, where the trenches were of designedly smaller profile, the traverses were 5 yards in breadth and 4 yards in depth. The fire bays between traverses were about 11 yards in length. A broken trace was freely used, when the alignment of the trench permitted, in lieu of traverses.

The communication trenches were of much smaller cross section than the parallels, except where organized for use in connection with the defensive scheme. Many of the communication trenches were but 4 feet deep; 6 feet appeared to be the maximum depth, where used for communication only. Communication trenches were often quite narrow, sometimes as little as 5 feet at parapet level.

No duck-boards whatever were placed, except occasionally immediately in rear of entrance to the more elaborate shelters.

The parapet and parados were very flat. Despite the very large cross-section of the trenches the height of the parapet above ground level was not more than a foot and a half. They were neither designedly rough or designedly smooth—the earth was merely thrown out and spread.

It may be said that the trenches were unaffected by our artillery preparation. In no case were they so blocked by débris as not to afford covered communication.

WIRE ENTANGLEMENTS.

All wire entanglements were extremely dense, and were normally made of the extremely heavy German wire, closely set with barbs.

The posts were 2 feet 6 inches and 4 feet in height above ground. Some of the belts were set wholly with high posts, some wholly with low posts and some had the two types interspersed. The high posts were generally of angle iron of the usual type, with notches to catch the wire. The low posts were often of wood, but occasionally were screw pickets or short angle-iron posts. The wire was attached to the wooden posts with staples, and was normally not wrapped around the posts. It is interesting to note that the wooden posts, certainly not more than 2½ years in place, had in many cases become brash and brittle, and were easily broken.

The posts were usually placed in quinqunx order, and spaced 5 feet between posts, but in some of the belts the spacing was as much as 7 feet—rarely more. The wiring was quite complex, and

did not appear to follow any set type, although always very dense. One typical belt had first a net of ground wires as shown in Fig. 3, then a complete system of crossed diagonals on the same system, supplemented by a three-wire fence on the front and rear rows of stakes. Other belts were wired on the typical French system, but with a loose wire down the middle of each row, as shown in Fig. 4. This loose wire was fastened with a wrapping of fine wire to the diagonals at each intersection.

All wire was strung very loosely indeed.

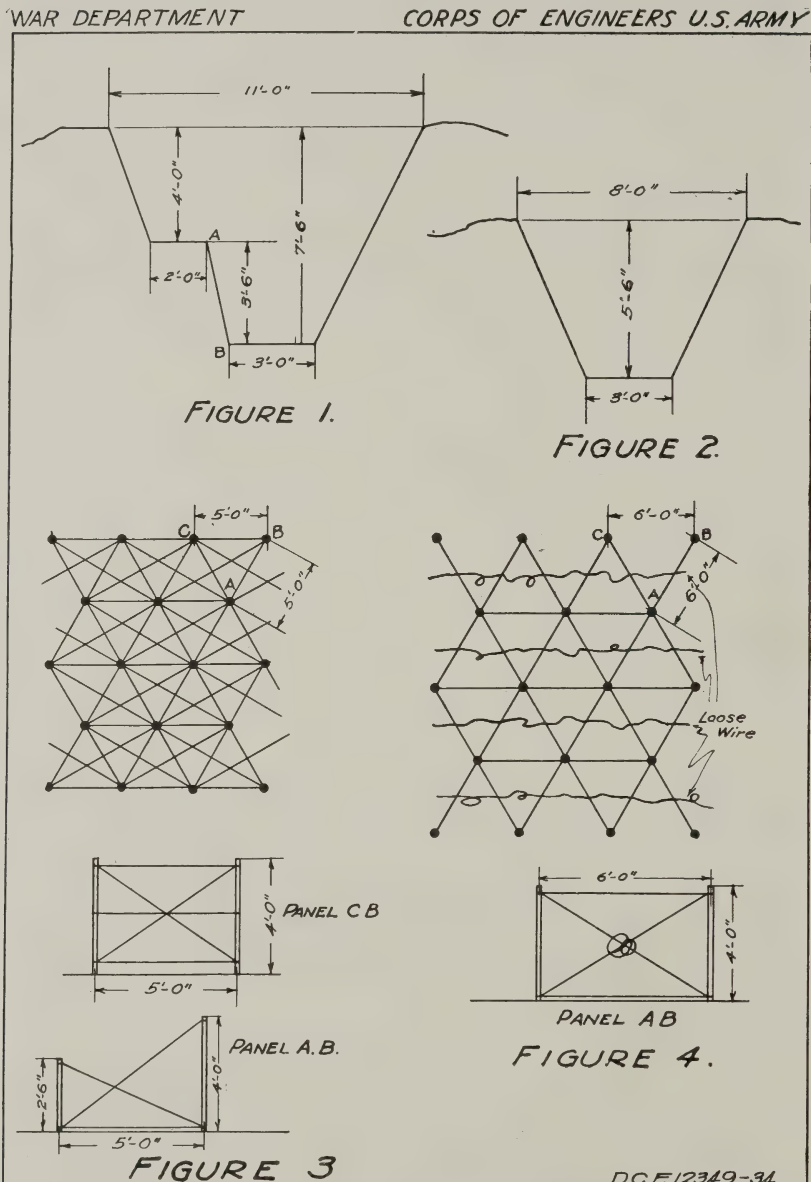
The belts were of varying depths, from 5 to 10 yards. There were at least two belts of wire in front of each line of trench, separated by intervals ranging from 10 yards upward, and many cross and diagonal belts between and in front of the lines. The inner belt was probably 30 yards from the trench, on an average, but by no means paralleled the alignment of the trench. The inner belts had normally a height of 4 feet, the outer belts 2 feet 6 inches. The belts were arranged in straight reaches, from fifty up to several hundred yards in length, and were flanked by machine-gun fire. In so complex a system, it is impossible to be sure that every reach of wire was flanked by machine-gun fire, but in every case where it was tried, at least, a machine-gun emplacement of some sort was found on a line in prolongation with the outer edge of the belt chosen. In very few cases, however, could the wire be flanked by blind laying of the machine guns. Aiming in elevation was necessary to cover the belt.

Little of the wire was actually destroyed by our artillery fire, although much was badly shaken. occasional posts being blown out, and some wires cut. The wooden posts suffered most, a considerable number being broken. Despite the substantial integrity of the wire, and despite the fact that the tracks made by the tanks were few and far between, our assaulting force had little difficulty in picking their way through the wire and keeping up with the barrage.

SHELTERS.

Shelters were of three classes: light shelters under the parapet, cave shelters (mined dugouts), and concrete shelters.

Light shelters were found only in the advanced line in front of Bellicourt. These shelters (Fig. 5) had their floor about 3 feet below the sole of the trench, and were entered by an approach, with 3 or 4 steps down, formed of standard mine cases, set verti-


WAR DEPARTMENT
CORPS OF ENGINEERS U.S. ARMY
11'-0"
4'-0"
7'-6"
A
2'-0"
3'-6"
B
3'-0"
FIGURE 1.
8'-0"
5'-6"
3'-0"
FIGURE 2.
5'-0"
C
B
A
5'-0"
PANEL CB
4'-0"
5'-0"
PANEL A.B.
2'-6"
4'-0"
5'-0"
FIGURE 3
6'-0"
C
B
A
6'-0"
Loose Wire
6'-0"
4'-0"
PANEL AB
FIGURE 4.
D.C.F. 12349-34

cally. The shelter itself was lined with corrugated iron, of the type shown in Fig. 7, "Engineer Field Notes No. 31" (French Individual Shelter) probably of captured material.

A flat sheet of corrugated iron was always placed over the entrance, which, in this type of trench, had rarely as much as 2 feet of overhead protection.

Few, if any, of these shelters had been destroyed by the artillery preparation.

Cave shelters were very plentifully provided in the Hindenburg trenches proper, and were in the front lines (except the advanced line in front of Bellicourt) as well as in the rear lines. The entrances averaged one to every 40 yards of trench front, although, of course, not uniformly spaced at this distance. Considering the two lines, and additional dugouts in rear, and assuming one dugout to every two entrances, there are at least 50 cave shelters and 100 gallery entrances per mile of front in this sector.

Some of the entrances had been blown in, and many other entrances had caved where our troops had removed the lining, so that it was not possible to make any extended investigation of the cave shelter construction as here practiced. All shelters entered had 30 feet of overhead cover, and had two exits, either into separate fire bays of the trench; or one entrance to the trench, and one to a machine-gun emplacement outside of the trench. The rooms (of those entered) were formed as niches off the gallery connecting the two entrances, and were small.

The entrance galleries were invariably lined with mine cases, and had usually an inside width of 4 feet, and an inside slant length of 5 feet 4 inches, giving a vertical height of 6 feet, or a trifle more. The cases were almost invariably placed normal to the slope of the gallery. Vertically placed casing was most unusual. An interesting feature of entrance gallery construction was the occasional use of straps of flat iron, about 3-16 inch by 1¼ inches, slotted for nails, which were run longitudinally down the galleries to prevent the cases from spreading. A few of the entrance galleries had supporting bracing placed inside of the cases on each side, as shown in Fig. 6. Cross-struts connected the upper chords of this bracing, but these struts were few and small. The utility of such bracing seems very problematical.

The lining of the approach to the entrance was arranged in various ways. The slope of the first casing was almost invariably

the interior slope of the parapet, which was 3 vertical to 1 horizontal. The angle of descent of the gallery was normally 1 on 1. The angle between these slopes was usually turned by using two wedge shaped side cases, as shown in Fig. 7, these being toe-nailed at the bottom. Sometimes the angle was turned by cutting the side cases as shown in Fig. 8, the cut side cases being in this case toe-nailed to the entrance set. Where the bracing shown in Fig. 6 was used, the first set was nearly vertical and the entrance sheeted as shown. In a few instances, also, the galleries started with the full slope of 45°, the trench slopes being cut back to this slope in the vicinity.

The approaches had, almost invariably, at least 3 feet of overhead cover, and often more, the trench being locally deepened. In one or two instances, where the drainage problem apparently prevented the excavation of the trench to sufficient depth, a grillage or railroad ties, three layers deep and closely set, was placed over the entrance.

In a few cases the entrance galleries to cave shelters located in rear of the trench line opened into a concrete shelter at the surface, as shown in Fig. 9, affording a double-deck command post, where the officers could live and work in light and comfort and sleep in safety. The posts of this character met with were either in the ruins of villages, or in short offset trenches.

It might be thought that the inclination of the approaches to the entrance would disclose their existence on airplane photographs. The maps prepared from the photographs indicate some, but by no means all, of the entrances. In any event, when the entrances are so numerous throughout the trench, it matters little whether their existence is known or not.

In a few cases also, the approach to the entrance of a cave shelter was constructed of concrete, as an integral part of a concrete shelter adjacent to the entrance, as shown in Fig. 10. No concrete was used to protect the entrances, however, when they were not constructed in connection with a concrete structure.

The destruction of the entrances by deliberate demolition or by abstracting the lining was so widespread, that it is impossible to judge of the destruction caused by the artillery preparation. One may judge, however, that but few were so destroyed.

Shelters of re-enforced concrete were fairly numerous. They were placed at salients and near the roads, generally in the front

line, but occasionally in the rear lines, with occasional concrete shelters for machine-gun crews in front or in rear of the trenches, and for command posts in rear. Altogether, 34 of these shelters were counted by the two parties, on the 6,000-yard front, but there are probably quite a few more detached ones that were not discovered.

The concrete shelters were of various designs. The predominant type of those placed in the trenches is shown in Fig. 11. These were located in the fire bays, the rear wall flush with the interior slope of the trench, and having the same batter. The thickness of the frontal protection was not measured, but is probably 5 feet. The thickness of the floor is likewise not certainly known. A drain in one of the shelters showed 3 feet of concrete. To be sure, the drain may have been boxed with concrete, but it seems likely that this represents the thickness of the floor.

In all cases provision was made for a fire step along the rear face of shelters of this type, in continuation of the normal fire step of the trench. In a few cases the step was moulded of concrete, as shown in Fig. 11a, usually, however, provision was made for a wooden step in the form of a plank supported by brackets of strap iron set in the concrete, as shown in Fig. 12. Sometimes a second line of brackets, for a lower step, were placed, as shown by the dotted line. In the form of defense used, and the state of the trenches, these steps served no particularly useful purpose.

Each of the two interior rooms was ventilated through a small hole through the roof, entering a slot formed in the interior front wall. In one case two additional slits had been cut through the rear wall, for additional light and ventilation. A feature of this type of shelter was the heavy wooden doors at the entrance proper to the interior rooms. These were formed of a layer of 2-inch plank crossed by a layer of 1-inch boards, and were cut horizontally into an upper and lower leaf.

Another type of shelter, occurring in a group of six south of Bellicourt, is shown in Fig. 13. It will be noticed that this shelter has much thinner protection, and has but 4 feet 10 inches headroom. Unfortunately, none of the group was hit.

There were also a number of other shelters of miscellaneous design. A rather elaborate entrance protection is shown in Fig. 14. The overhead cover of concrete was about 3 feet in thickness. This shelter was located in a short camouflaged trench in rear of the

WAR DEPARTMENT CORPS OF ENGINEERS U.S. ARMY

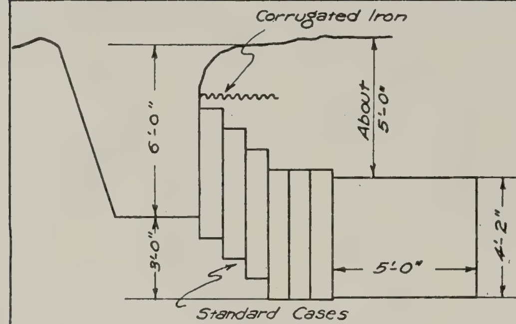


FIGURE 5

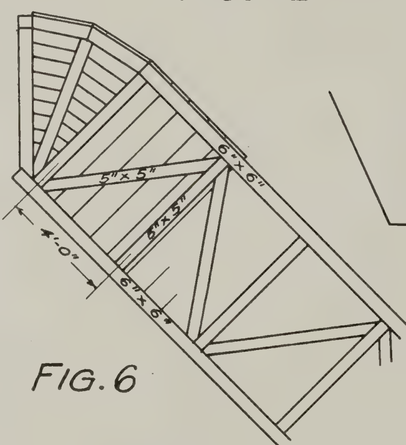


FIG. 6

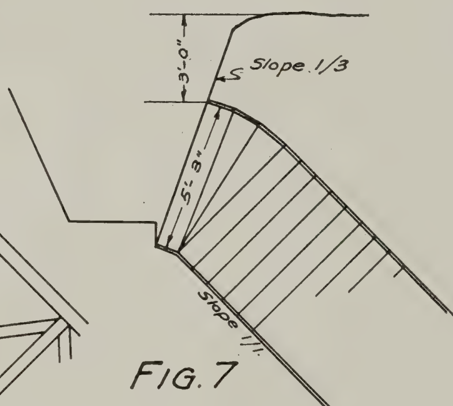


FIG. 7

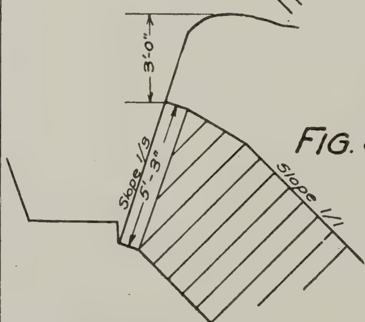


FIG. 8.

D.C.F. 12350-34

line, dug so deep that the shelter was entered at floor level without steps. Steps in the trench lead to an open machine-gun emplacement. Entrance to the trench was through a blinded sap lined with arched corrugated iron.

A simpler shelter for a machine-gun crew is shown in plan in Fig. 15. This was located in the advanced line, near the Bellicourt-Hargicourt road. The recesses for storing the machine guns may be noted. The weakening of the wall consequent to one of these undoubtedly contributed to the partial failure of the shelter, as later described.

MACHINE GUN EMPLACEMENTS.

The machine guns firing from the trenches (and there were many of them) had no elaborately prepared emplacements. The necessary means of access to the parapet from a nearby shelter was prepared, and the gun run up into action. Occasionally a semi-circular platform of planks was arranged for this purpose, but not often.

There were a number of open machine-gun emplacements of concrete, of the type shown in Fig. 16, located either in front of or behind the trenches and connected by deep underground passages to shelters entered from the trenches. The design of these emplacements, as concerning the firing stand, was by no means uniform. Some were merely an open concrete box. The thickness of the concrete protection was in all cases 3 feet or more.

These emplacements are very hard to discover in a more or less hasty visit to the lines, as one happens on them accidently only, unless one finds them as a consequence of exploring the cave shelter to which they are connected. It is difficult to estimate how many were installed.

Machine-gun emplacements with overhead protection, the so-called pill-boxes, were very few—probably numbering not more than three in the whole sector of the American attack. One closely examined is shown in Fig. 17. It was constructed in the spoil bank of the canal, a wide embrasure being excavated in the bank to afford the necessary field of fire. It does not appear to have been located as such by airplane photographs, although the embrasure was not, apparently, camouflaged. A noticeable feature, common to the type, is the roof formed of closely set I-beams, the lower flanges exposed. The type here shown may be compared with Figs. 4 and 5, "Engineer Field Notes No. 33." The reen-

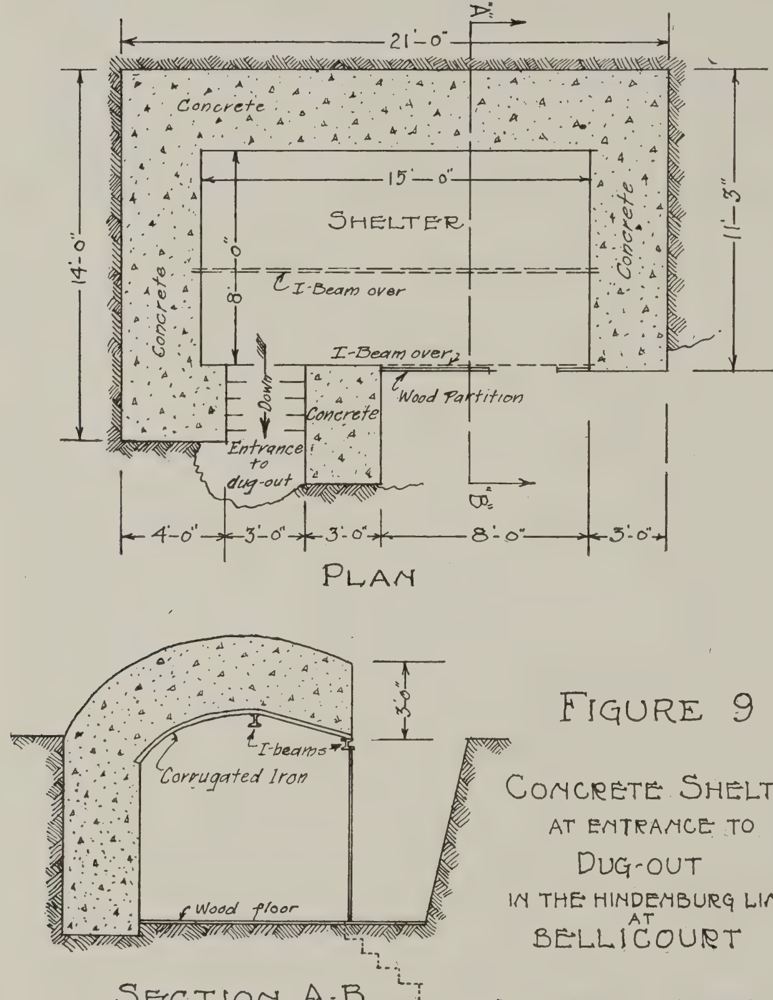


FIGURE 9

CONCRETE SHELTER
AT ENTRANCE TO
DUG-OUT
IN THE HINDENBURG LINE
AT
BELLICOURT

Dimensions are Approximate

OFFICE OF THE CHIEF ENGINEER, II CORPS AMERICAN E. F.

D.C.F. 12353-34

forcement, however, is not believed to follow the system there shown, but is believed to be the same as that hereafter described.

None of the concrete machine-gun emplacements found had been hit by our artillery.

OBSERVATION POSTS.

The position of the lines was such, in general, as to give observation from elevations in rear. Very few observation posts, as such, were discovered. One interesting type of concrete observation post is shown in Fig. 18, and consisted of a concrete box set flush with the ground, covered by a steel plate provided with a hole, about 12 inches in diameter, through which the head of the observer or a periscope could be thrust. One such observation station was found on the summit of a mound in the town of Bellicourt, and a pair were found in the midst of the wire in front of the front-line trench, where observation was very good. There are undoubtedly others not discovered. The pair last referred to were installed as a part of an elaborate structure that may be called a concrete listening post. It had two stories, the plan of the lower being shown in Fig. 18. The two observation compartments were placed over the middle two rooms, and an open machine-gun emplacement of the type shown in Fig. 16 was placed over the right-hand room. Access to the machine-gun emplacement was had through a short trench, entered from this right-hand compartment. The left-hand compartment of the lower story was the entry to a deep underground passage, leading to a concrete shelter in the parapet of the main front line trench, about 40 yards in rear of the listening post. In point of fact this passage seems to have been used by the Germans as a dumping place for empty bottles, discarded equipment, and all manner of rubbish, rather than as an entrance to the advanced post.

One very light plank observing post, with a camouflaged slot for observation, was found in the front line trench near Bony. There was nothing new or interesting in this structure.

MISCELLANEOUS FEATURES.

Parts of the line were well provided with latrines of the ordinary box-seat variety, without overhead cover, placed in short trenches leading off from the parallels.

A large sized mortar emplacement was found in front of Bellicourt. It was an excavation in the form of an inverted pyra-

WAR DEPARTMENT CORPS OF ENGINEERS U.S. ARMY

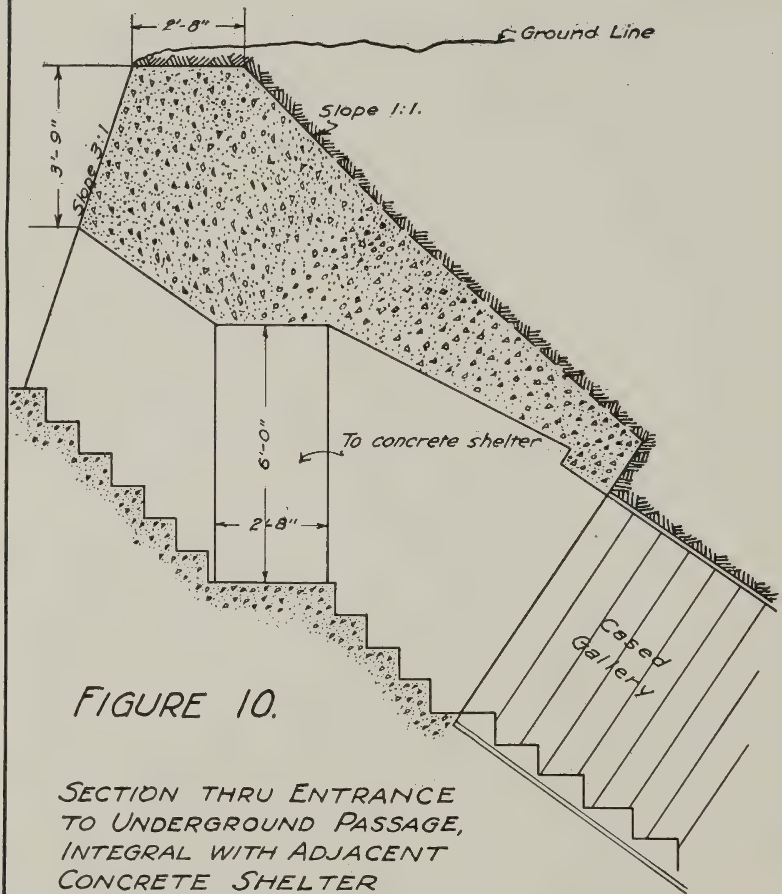


FIGURE 10.

SECTION THRU ENTRANCE TO UNDERGROUND PASSAGE, INTEGRAL WITH ADJACENT CONCRETE SHELTER

D.C.F.-12313-34

mid, with front and side slopes about 1 on 1, rear slope vertical, 15 to 20 feet in depth, and lined with heavy timbers. The rear half was lightly roofed over and camouflaged. It was entered through an underground passage from the rear.

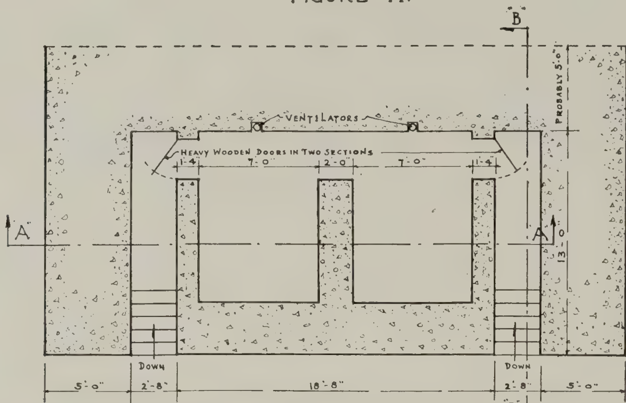
In front of the second line trenches near Bellicourt (which are believed to have been originally the front-line trenches of this part of the sector) there are a number of large excavations, probably 60 feet in length, 40 feet in width at the surface of the ground, and 15 feet or more in depth; roughly rectangular in shape, with the longer side parallel to the trench line. The ridge of earth between these excavations and the trench was not more than 5 yards in width. The earth excavated had been spread around the hole. It would be interesting to know what these holes were intended for. There was no sign of a camouflaged covering, such as would be necessary that they might serve as tank traps. It is possible that they were excavated for concrete shelters, and that the decision was subsequently made to locate the shelters in a different position with respect to the trench line.

RE-ENFORCED CONCRETE.

The concrete used in this section of the line had gravel as an aggregate. Although the gravel had been brought from a considerable distance, there being no local material suitable for making concrete, it was of decidedly inferior quality, there being a large excess of fine aggregate. The concrete was more of a mortar with an admixture of pebbles than a hard mass of cemented stone. Those faces of the various works that were not intended to bear the light of day were very rough, and showed many voids. Exposed faces were plastered. The finish of such faces was very good, and showed no signs of checking or scaling. One would say that the concrete was mixed much drier than is the American practice, and that the consequent rough surface holds a plaster coat much more tenaciously than the relatively smooth surface produced by our wet mixture.

From the fact that every broken face—and many not broken—showed re-enforcement of a uniform character, one may judge that all concrete in this sector was re-enforced on a uniform system. The re-enforcement was formed of plain round rods from $5/8$ to $7/8$ inch in diameter. These had very evidently been placed in the mass as the concreting progressed; not set and wired before the

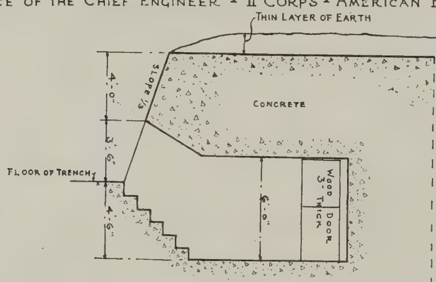
FIGURE 11.



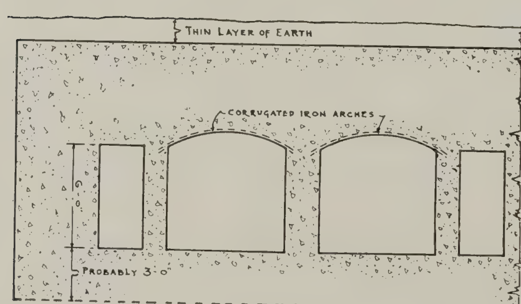
PLAN AT FLOOR OF TRENCH
SCALE ¼" = 1'-0"

- TYPICAL CONCRETE SHELTER -
- HINDENBURG LINE NEAR BELLICOURT -

- OFFICE OF THE CHIEF ENGINEER - II CORPS - AMERICAN E.F. -



- SECTION THRU ENTRANCES AT B-B -



- SECTION A-A -

D.C.F. 12354-34

concreting begun. For this reason there was no uniformity in spacing. I would judge that it was intended that all concrete should have a horizontal course of crossed rods at vertical intervals of something between 6 inches and a foot. Each course consisted of two sets of rods, one at right angles to the other; the rods of each set being spaced between 6 inches and a foot apart. This re-enforcement was continued throughout the whole mass of the concrete, not concentrated at the top and bottom of the slab. The rods were not cut when the face of the form was reached, but were bent 180° to form the next line of the set. In very many cases the rods showed on the face of the concrete. In addition to the horizontal re-enforcement, vertical re-enforcement was used in the walls of the structure. It was not found in the roofs.

The effect of artillery fire on re-enforced concrete structures was carefully looked for, but unfortunately no structure was found that had been demolished. In all, four hits were found and studied. The first was on the edge of a concrete shelter at the entrance of a dugout (Fig. 9). Possibly 6 inches in depth of concrete was obliterated, and the concrete disintegrated into the consistency of bank gravel for a further depth of about 2 feet. There were no signs of any effect on the interior of the shelter.

The second hit was on an upper corner of the concrete listening post, Fig. 18. About 2 feet, in depth, of concrete was obliterated, leaving the re-enforcement in place, and the concrete was disintegrated, as in the first case, to a further depth of about 2 feet. There were no signs of any effect on the interior of the shelter.

The third hit was on the roof of the shelter shown in Fig. 14. This roof probably was 1 meter in thickness, covered with about 1 foot of earth. The explosion did not lay bare the concrete, but shook the plastering off the ceiling inside.

The fourth hit was on the shelter shown in Fig. 15. There a shell, penetrating the earth backfill next to the shelter, blew in the side wall just above the floor level, between the machine gun recess and the corner of the room, as indicated in the illustration. Possibly half a cubic yard of concrete was thrown in. The effect was the same as that previously noticed in other cases of underground explosion, in that it seemed to be rather in the nature of the breaking or scaling off of masses of the face by transmitted shock, rather than a displacement of the wall as a

WAR DEPARTMENT CORPS OF ENGINEERS U.S. ARMY

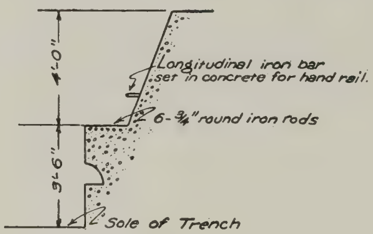


FIG. 11.a

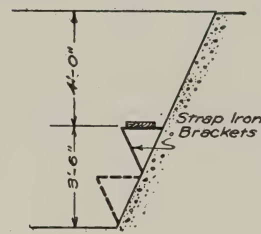


FIG. 12

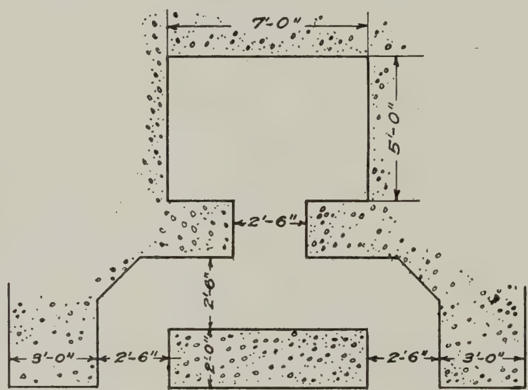


FIG 14.

D.C.F. 12352-31

whole from the center of the explosion outward. The exterior portion of the wall seemed substantially intact. The re-enforcement of the portion destroyed was very meagre, consisting of but two pieces of angle-iron picket, placed at random, and one horizontal $\frac{3}{4}$-inch round iron rod. I think there is good reason to suppose that the wall would have stood, had the re-enforcement been up to standard.

The damage to this shelter occurred some time prior to the attack, for the broken concrete had been thrown out and the shelter reoccupied.

A shell striking in front of the observing station on the mound at Bellicourt had laid bare the front face of the concrete, without in any way injuring it.

THE ORGANIZATION OF THE CANAL TUNNEL.

The trenches were from 500 to 1,000 yards in front of the line of the canal tunnel. This tunnel is about 26 feet in width at the level of the towpath, and about 26 feet in height from the bottom of the canal to the crown of the arch. It lies between 100 and 200 feet below the ground surface. It designedly lies below ground water level, to the end that it may provide water for the summit level of the canal, and the canal in this sector is consequently always full of water. There is a towpath, 4 feet 6 inches wide, in the tunnel on the east side.

The exploration disclosed eighteen entrances, either mine galleries or shafts equipped with platforms and ladders, constructed by the Germans to afford access to the canal. There are four exits from the tunnel south of Bellicourt to the rear line trench of the Hindenburg system in that locality or to its communicating trenches; four exits into the town of Bellicourt; seven exits into a parallel in the rear of the Hindenburg line, near the north end of the sector, and three exits in the long stretch of about 2 miles between Bellicourt and this northerly approach. Just inside of the south end of the tunnel a concrete wall had been constructed, pierced with holes for machine-gun fire, by which the entrance could be defended and the adjacent deep cut of the approach enfiladed. A second bulkhead, 3,800 feet to the north, and under the town of Bellicourt, was likewise organized for machine-gun fire, with a view to preventing any hostile parties who might enter from penetrating further southward. The canal between the bulkheads was filled with canal boats, and these were connected to the

WAR DEPARTMENT CORPS OF ENGINEERS U.S. ARMY

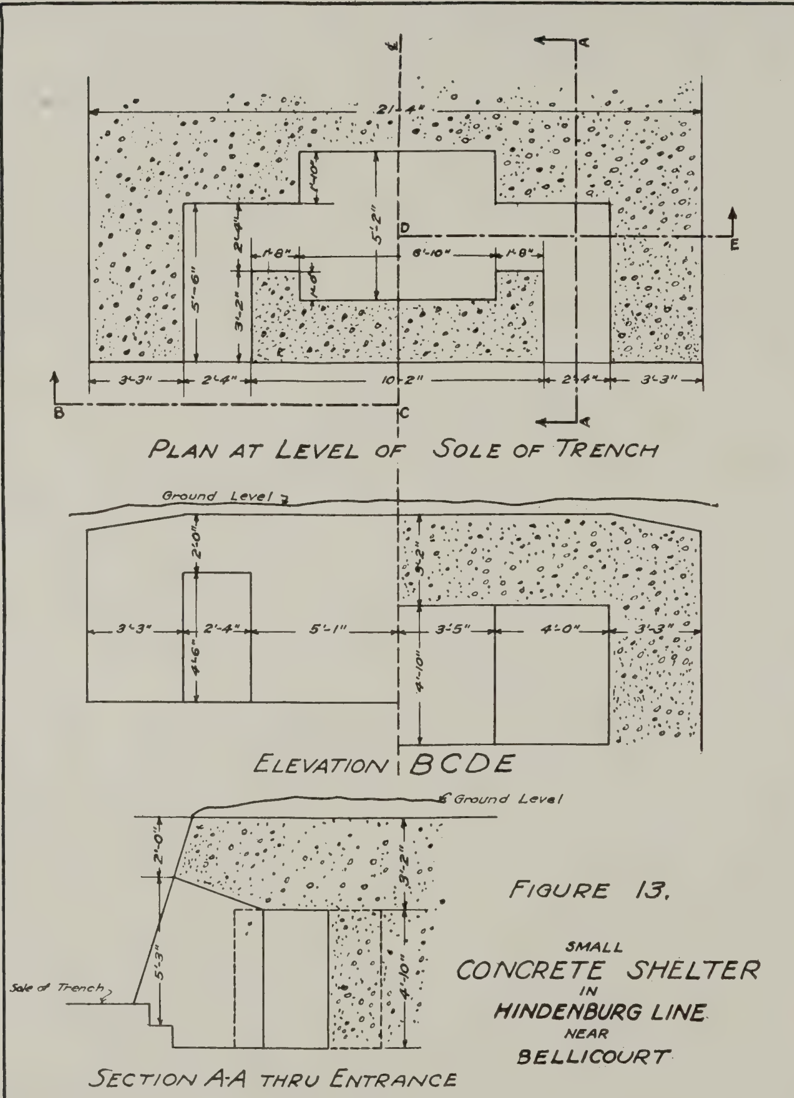


FIGURE 13.

SMALL CONCRETE SHELTER IN HINDENBURG LINE NEAR BELLICOURT

D.C.F.-12315-34

WAR DEPARTMENT CORPS OF ENGINEERS U. S. ARMY

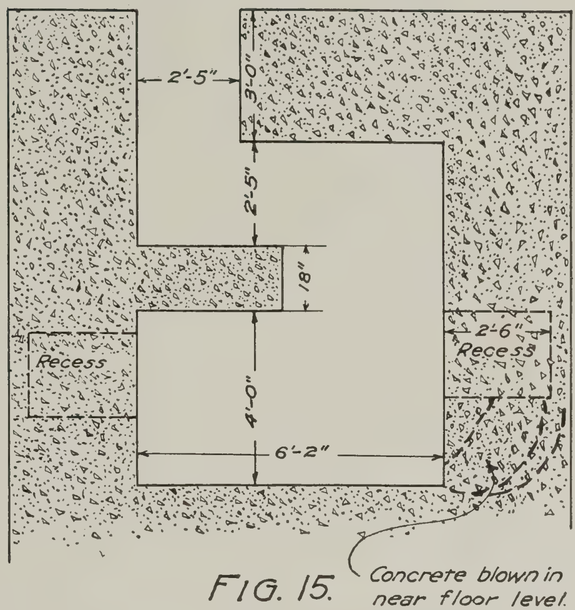


FIG. 15.

PLAN
OF
CONCRETE SHELTER
FOR
M. G. GUN CREW
FRONT LINE OF HINDENBURG SYSTEM
NEAR
BELLICOURT
Scale 3/8" = 1'-0"

D.C.F.-12312-34

towpath by a continuous board platform. They were evidently intended for quartering troops. A generating plant for the supply of electric current, two engine-driven air compressors, and storerooms for the storage of gasoline and oil, were located in rooms off the tunnel.

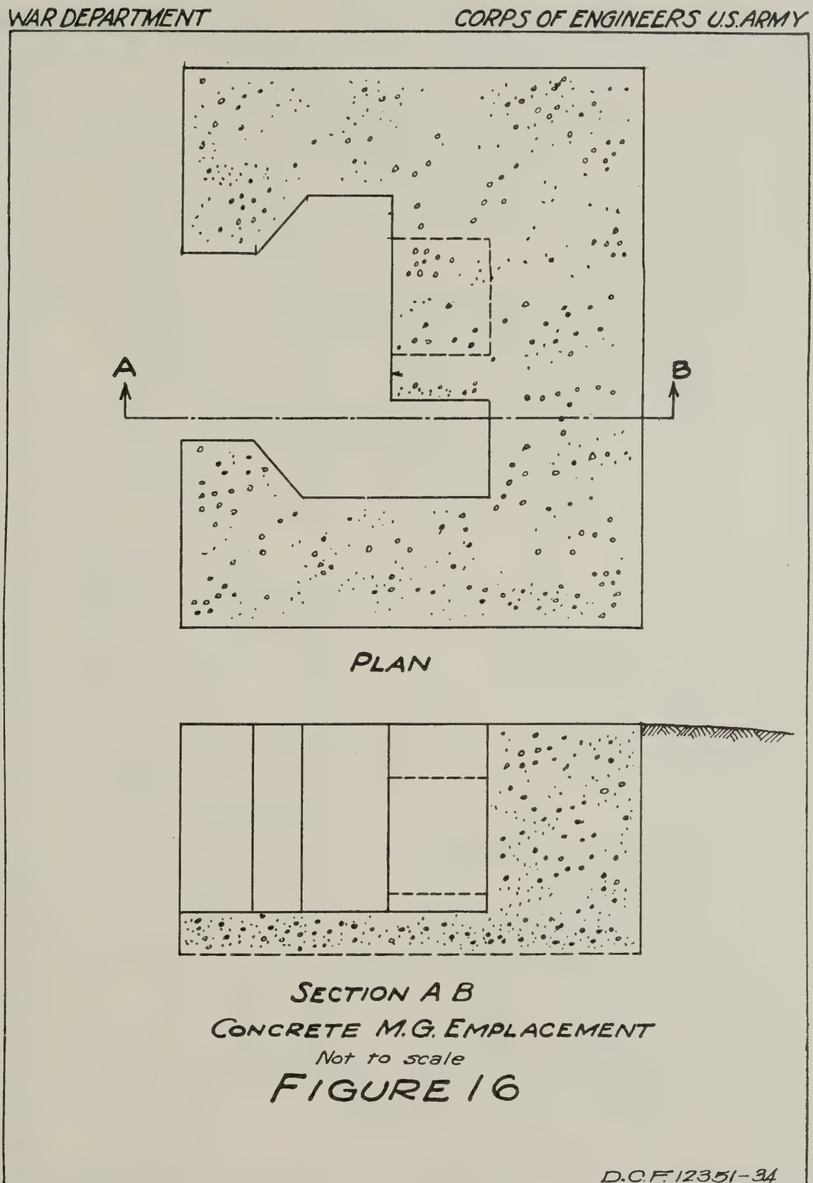
It seems very clear that, outside of its use for a site for the machine-gun emplacements flanking the canal to the south, the canal tunnel was used by the Germans solely as a shelter for reserves and for power plants. The exits provided were neither sufficient in number nor so located as to permit the reinforcement of either the front or support line directly. The tunnel afforded, indeed, an opportunity for the concentration of a large body of troops in safety immediately behind the line, but otherwise did not enter into the scheme of defense. It is so wet that it could not have been a very agreeable resting place for a regular garrison.

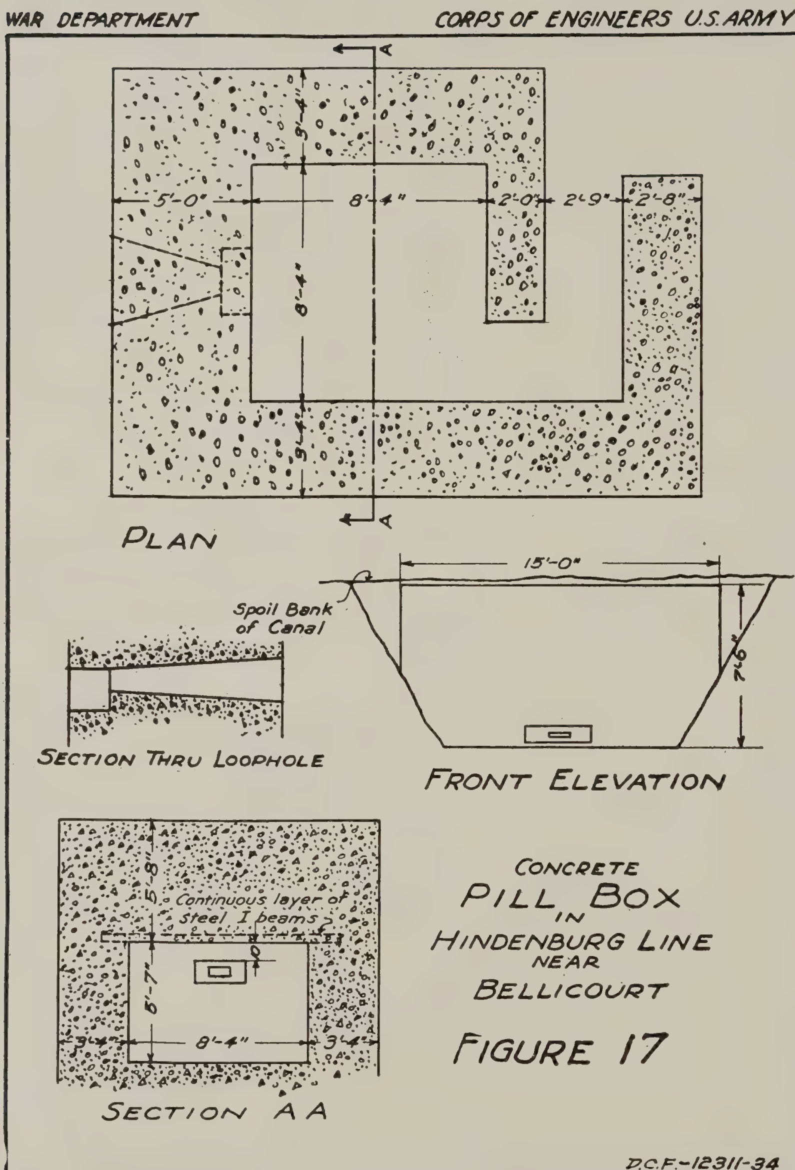
LESSONS TO BE DRAWN FROM THE ATTACK.

The attack was made behind a barrage. The morning was very foggy. On the right half of the sector, the attack was completely successful. Most of the machine-gun nests were captured before their guns came into action. On the left half some of the attacking elements penetrated the main line of defense; but groups of the defenders remained in action, and retained possession of the ground, so at the end of the day the enemy still held the outpost line. Two points therefore stand out: first, that the most elaborate defense fell before an assault, delivered under overwhelming fire superiority; second, that very much less elaborate defense, resolutely held, checked such an assault. The fundamental lesson is therefore the one as ancient as history: that it is not the position, but the men in it that assure the defense.

The next lesson, also an old one, is that the works of defense should be well dispersed. If the concrete structures had been concentrated in a few forts, there would undoubtedly have been a real opportunity to observe the effect of artillery fire on such works. Scattered as they were, ten times the volume artillery preparation would not have achieved the destruction of any considerable number.

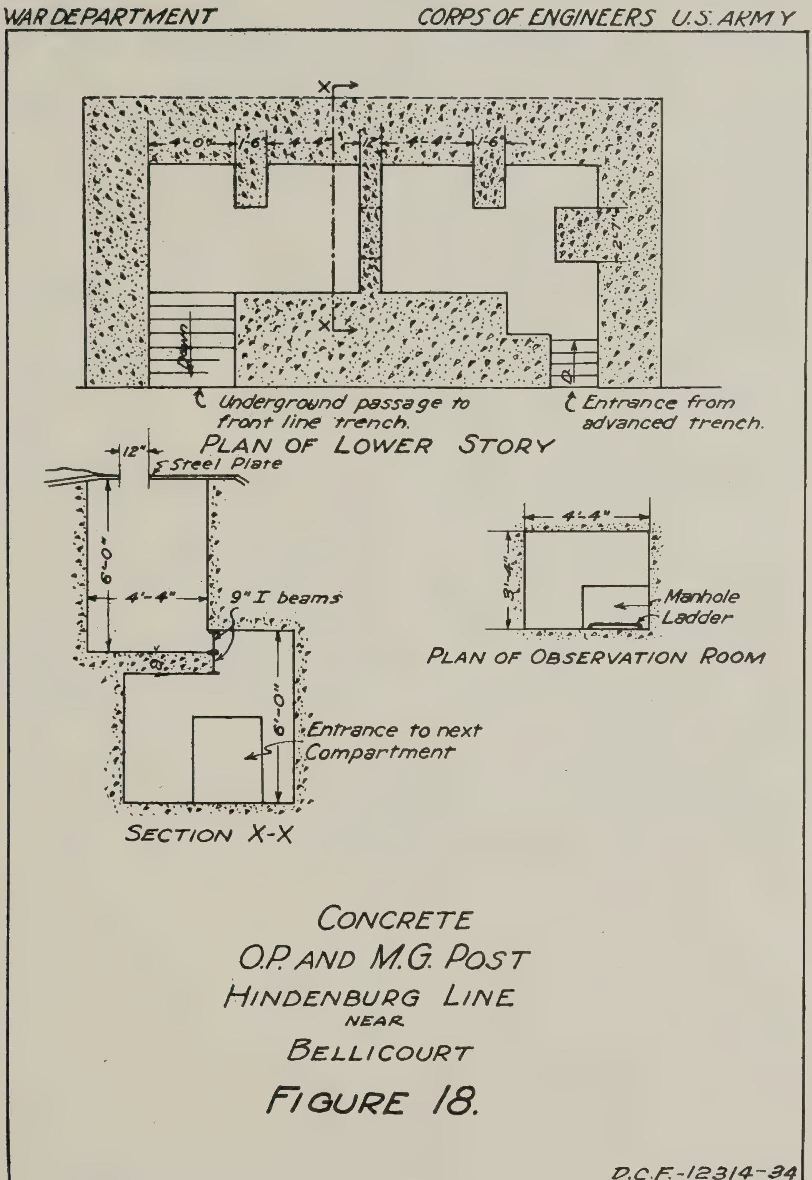
The new lessons in detail are most difficult to draw. Based on the very insufficient evidence that the single failure found in a concrete shelter occurred at a point where the reinforcement was wholly inadequate and far below standard, one would say that all


WAR DEPARTMENT
CORPS OF ENGINEERS U.S. ARMY
A
B
PLAN
SECTION A B
CONCRETE M.G. EMPLACEMENT
Not to scale
FIGURE 16
D.C.F. 12351-34



CONCRETE PILL BOX IN HINDENBURG LINE NEAR BELLICOURT

FIGURE 17



CONCRETE
O.P. AND M.G. POST
HINDENBURG LINE
NEAR
BELLICOURT

FIGURE 18.

concrete, even to be bottoms of all walls, should be reinforced. Considering, too, the observed disintegration of the concrete where struck by a H. E. shell, coupled with the very limited radius of this destruction, one would say that the reinforcement should not be limited to the top and bottoms of the slab, but should continue throughout the mass; for after a shell has hit, there will be a new top surface.

Assuming that we continue to use concrete in fortification work, the question of the size and spacing of the reinforcement to develop in the concrete the maximum resistance to shock seems worthy of investigation and experiment. The very decided impression formed from the examination of the hits on reinforced concrete was that considerably lighter reinforcement would have equally well served the purpose.

It is unfortunately impossible to do more than guess the caliber of the projectiles scoring the few hits found. One may guess, however, that 3 feet of reinforced concrete, over a span of not more than 8 feet, will stand all the pounding that there is any chance of its receiving from an ordinary field gun, and that 5 feet will stand everything that it is likely to receive from guns up to 8-inch caliber, certainly. Equally as well, if the structure presents one well defined target, on which the enemy believes it worth while to concentrate an unlimited amount of artillery for an indefinite period, until it is demolished, no reasonable thickness of concrete will stand the test.

Lastly, one may judge that however useful underground tunnels may be in reducing casualties in long continued trench warfare, they are useless in the organization of a position to resist an assault.

MEMORANDA ON THE CAMOUFLAGE SERVICE OF THE UNITED STATES ARMY.

By

Maj. Evarts Tracy,
Engineers, U. S. A.

Although the subject of Camouflage had aroused much interest before the entrance of the United States in the war, among architects, artists and sculptors, some of whom had attended officers training camps at Plattsburg, and through correspondence with former fellow-students at Paris and at that time in the Camouflage Service of the French Army, had gathered information slightly less vague than that of the army and public in general, no preparation for this branch of the service was made until the receipt of a telegram from General Pershing on August 3rd, 1917, asking for the formation of one Camouflage Company of Engineers.

A reserve Major of Engineers was immediately detailed on the staff of the Chief of Engineers at Washington with orders to organize the new service and recruit the required Company.

The work of organizing was immediately started for the first Company at Camp American University, afterwards Camp Leach, near Washington.

A nucleus of officers was selected from men who had recently been commissioned at the first student officer camps and ordered to report at once. These officers were from the architectural and artistic professions and some of them had observed the camouflage of the French in the earlier stages of the war.

Through the assistance of the National artistic societies of the United States a card catalogue of over 7,000 names of men of military age and considered suitable for the work was made. Nearly every man on this list was known to at least one of the officers of the new service and his personal qualifications were carefully considered. A number of first-class mechanics of many trades, such as carpenters, blacksmiths, machinists, painters, stage carpenters and property men, moving picture scene constructors, etc., were carefully selected and the first Company was made up from these lists.

This method of selection resulted in the enlistment of many of the leaders of the artistic profession, and the best of the mechanics in the country.

It was found, not only by our higher officers, but by our allies, that skilled architects as a rule made the best field camoufleurs, although there are brilliant exceptions, as appeared in our own organization.

The field camoufleur should of course have as broad a knowledge as possible of the tactical employment of the arms of the different branches of the service, particularly artillery, and in addition should possess constructive ingenuity, a fine sense of color and artistic perception, imagination and ability to handle men.

The skilled engineer will have most of these qualities, but often lacks the artistic ones.

The artist possesses color sense and artistic perception but is apt to lack the leadership qualification.

The education and experience of the skilled architect seems more often to develop all these necessary qualities. If he is a success in his profession he must have the artistic qualities and he must have developed the ability to handle men through his superintendence of important buildings.

The first Camouflage Company was originally organized as a unit of a shop and supply regiment, but on advices from Europe and careful consideration it became evident that it could only function efficiently as an independent unit, and eventually became Co. A, 40th Engineers, N. A.

The greater part of the time up to its departure overseas in January, 1918, was occupied in perfecting the organization, infantry drill and much experimental work in camouflage. Nearly all of the camouflage work done by the Company was original because of the apparent impossibility of getting any information on the subject from Europe and was not as valuable as if such information had been received. The Company had, however, a very remarkable high class personnel, was well equipped, disciplined and drilled, and provided extremely efficient work both at the factory and in the field.

A short time before the cable ordering the organization of the Camouflage service arrived, a nucleus had been formed in France by the commissioning as officers of five men: architects, artists and sculptors who were in France at that time, with whom was associ-

ated for liaison a well known artist, a sergeant in the French camouflage service.

In September, Maj. H. S. Bennion, Corps of Engineers, U. S. Army, now Lieutenant Colonel, was assigned to the Camouflage Section as Commanding Officer. The time of these Reserve Officers for the first two months was for the most part occupied in visits to the British and French fronts and the various camouflage factories, familiarizing themselves with conditions in the field and factory methods.

The Moulin de la Galette, before the war a well-known dance hall on the summit of Montmartre in Paris, was leased for a camouflage factory and a small amount of camouflage material was being turned out by about one hundred French women and twenty enlisted men of the U. S. Engineers, consisting for the most part of Artillery flat-top covers, aeroplane hangar covers and sniper suits.

On October 3rd, 1917, the officer in charge of organization at Washington and three lieutenants, two of whom were chemists, skilled in dyes, paints and colors, and had been asked for by General Pershing, embarked for France, and reported on arrival to the Commanding Officer, Camouflage Section, at Paris. Until the 1st of January, 1918, the time was employed by visits to different British and French fronts, study of methods of factory practice both by British and French, organization of supply system and relation to troops, purchase and working up materials at the Paris factory, and the search and negotiations for a factory site for the A. E. F.

The factory was finally located at Dijon, Cote d'Or, about 240 miles southeast of Paris, where a field of some 20 acres was secured, and the erection of buildings immediately commenced, so that manufacturing was begun within twenty days. As the troops increased and went to the front, the plant expanded until at the time of the Armistice some forty buildings were in use. These comprised besides the usual barracks, mess halls, etc., warehouses, weaving sheds, carpenter shop, blacksmith and machine shop, toy shop, where dummies, silhouettes and all modeling and painting was done, paint shops, laboratory, women's lunch and rest rooms, and a creche where over a hundred babies, whose mothers were employed at the plant, were cared for. Some of the buildings were over 500 feet in length and the grounds were traversed by narrow-gauge railways.

Labor-saving machinery was made use of to as great an extent as possible, and all the special machinery such as painting and slitting machines, paint-mixers and hoists were designed by the section and built in the carpenter and machine shops, which were equipped to handle work as heavy as the ½-inch chrome-steel bullet-proof snipers and observation posts, which could only be fabricated by means of the oxy-acetyline blowpipe.

As an example of saving, after paint-mixing machines were installed, 2 men did the work that formerly required 40.

The personnel at the plant consisted of 4 commissioned officers, about 150 enlisted men and 900 French women.

The greater part of the output was for the concealment of artillery and the amount of cover required was enormous, sometimes over 4,000 square yards being required for a single battery of heavy guns with accessories.

Towards the end of the war, the daily output of artillery covers was about 50,000 square yards per day, composed of burlap strips, colored in the painting machines, and knotted on the fish-nets or chicken wire by women.

The daily output per woman in this class of work averaged 50 square yards for which she received about $1.25.

Very large numbers of covers for airplane hangars were made and painted with large mop brushes. These were on special orders as aviation fields were established toward the front, and required great amounts of material.

Over 3,000,000 square yards of burlap were required per month for artillery, engineer, and hangar camouflage. Some of the largest items besides burlap used monthly are as follows:

Paints, dry color: chrome yellow	tons..	490
Ultra marine blue	tons..	90
Other colors, including those ground in oil	tons..	100
Hide glue	tons..	90
Rope, ¼ to ½ inch diameter	feet..	1,620,000
Chicken wire	square yards..	2,200,000
Annealed iron wire	tons..	25
Fish-nets, 32′×32′ and 30′×40′	each..	8,800

The monthly production was valued at about $1,500,000.

This material in the field was erected under the supervision of the officers and enlisted men of the Camouflage Section by the units needing camouflage, usually at night and often under shell fire and gas attack. It had to be erected before any other work on a posi-

tion was begun, for otherwise an airphoto by the enemy would disclose the position, and the French artillery motto, "*Une batterie vue, c'est une batterie perdue*"—A battery seen is a battery lost—is absolutely true.

Company A, 40th Engineers, arrived in France in the latter part of January, 1918, and proceeded immediately to Dijon, from where, after the organization was thoroughly settled in its work, assignments were made of officers and detachments of enlisted men for service in the field.

At first there was no fixed numerical relation to other troops, and there always remained a certain amount of flexibility in these numerical relations, due to the terrain, protected by natural cover or not, stable or unstable sectors, preparations for an attack or withdrawal, and other constantly changing factors in such widely extended warfare.

The assignments were, however, always on a Divisional basis, with the Divisional Camouflage Officer on the Staff of the Divisional Engineer. Later, with the organization of armies, army and corps camouflage officers were assigned.

The organization of one camouflage battalion of two companies, in all 32 officers and 524 enlisted men was assigned as follows to each army, until the last few weeks of the war, when changing conditions rendered the concealment of artillery less necessary than heretofore.

It is not proper at this moment to discuss the latest developments.

As will be observed in the following tables, the camouflage of artillery was of paramount importance, although the other branches of the service were looked after when in need of camouflage service.

The limited personnel required the actual work of camouflage erection to be done by the troops needing the service, the enlisted men acting as supervisors and for the most part directing the work. For this reason high-class men were required, and many non-commissioned officers and officers, there being authorized for a company 66 non-commissioned officers and 32 commissioned officers in the battalion.

		Total—	
		Officers	Enlisted Men
Battalion Headquarters—			
Army camouflage officer	1	....	....
Officers for emergencies and replacements	5	....	....
	6	6	....
Enlisted personnel—			
Stenographer and typewriter	1	....	....
Records, etc.	1	....	....
General utility, messenger, orderly, etc.	1	....	....
	3		3
Army Artillery—			
Officer	1	1	....
Enlisted personnel—			
Office	1	....	....
Dumps	2	....	....
Field	18	....	....
			21
Corps Artillery—			
Officers	4	4	....
Enlisted personnel—			
Office	4	....	....
Dumps	8	....	....
Field	58	....	....
			70
Divisions—			
Officers	20	20	....
Enlisted personnel—			
Office	20	....	....
Dumps	20	....	....
Field	340	....	....
			380
Factory—			
Officer	1	1	....
Enlisted personnel	50	....	50
Total, 32 Officers, 524 Enlisted Men.			

In the very beginning it was evident that the great importance of camouflage in the war should be strongly impressed on all branches of the service.

It had been regarded by those who had not studied the subject to be more or less a joke, and as only the rarely used, theatrical devices came to the knowledge of those in America, the real and vital necessity as realized by our Allies was not appreciated.

After a short time in the line the lesson was forced on everyone,

but usually at the cost of considerable loss of life and matériel. For this reason it was decided to form a camouflage section in the Army Engineer School at Langres, the seat of the great university of post-graduate courses known as the Army Schools, which had as students every grade in the Army from the General Officers in the General Staff College to non-commissioned officers in the Candidates' School for Commissions.

The officer who organized the service in the United States was assigned to this school as chief instructor December 1st, 1917, and continued as such for six months.

PERSONNEL.

A. Officers—1 Chief Instructor;
6 Assistant Instructors.

B. Enlisted (1) 12 Enlisted men of the Camouflage Section, as assistants and demonstrators in camouflage erection.
(2) A detail from the A. E. F. post troops varying in strength as the work demands, this detail is made daily by the Post Commandant at request of Chief Instructor.

Lectures and demonstrations are given by instructors at the school to students of the various Army Schools, including:

General Staff College;
Field Officers School;
Superior Officers Artillery School;
Army School of the Line;
Trench Mortar School;
Infantry Specialists School;
Automatic Weapons School;
Intelligence School;
Candidates School, etc.

Lectures and demonstrations are also given by the officer personnel at the various above-mentioned schools in the Army School Area.

All students of the different sections of the Army Engineers' School are given instruction.

Classes of both Field and Heavy Artillery, including Officers and Non-commissioned Officers from the different Artillery camps of instruction, are sent to the School for an inclusive course in camouflage.

Officer instructors were also assigned to give lectures and

demonstrations at the different Corps Schools, Artillery Fields of Instruction and Intelligence Schools.

The result of this instruction soon began to show in the appreciation of the work in the field and the demand for officers and materials, which kept the factory working oftentimes day and night.

Major General Sumerall, when commanding the 1st Artillery Brigade, stated that he would as lieve go into action without ammunition as without camouflage, and that he considered one as important as the other.

Major General Traub, commanding the 35th Division, wrote a short time ago, "Camouflage, scientifically and intelligently carried out, is as important a factor in the success of our arms as any other single expedient possibly can be."

Actual results show that much loss of life and matériel was avoided by camouflage and its necessity is now deeply appreciated.

As long as airplane observation and photography exist, so long will there be need of camouflage.

COPY.

CAMOUFLAGE.

TRANSLATION OF GERMAN DOCUMENT:
From French IV Army Bulletin, Aug. 8, 1918.

1st Army
Command of the Aviation Service — Army Headquarters,
1a-1b — *July 1, 1918.*

I. ESSENTIAL POINTS IN THE CONSTRUCTION OF POSITIONS.

(a) *General*—

1. Camouflage will be completed before undertaking the work.
2. Camouflage will be sufficiently extensive in order that all the work required may be carried out under its protection.
3. Faulty installation will be left in place as dummy work and be begun over again at another point with the necessary prudence.

(b) *Tracks*—

1. Tracks must be as few as possible and have a natural appearance. It is best to avoid all tracks by building the position on roads already in existence.
2. Provide fixed access for everybody. If necessary, stake the paths out by means of wire.
3. Extend indispensable tracks beyond the position as far as the dummy work.
4. Use furrows as paths, do not go across fields.

5. Do not dump materials in the immediate neighborhood of the position.

(c) *Color of the Camouflage—*

1. Harmonize the color of the camouflage with the terrain. Green camouflage in meadows, brown in plowed fields, white in quarries.
2. The upper surface of the camouflage will be alternate light and dark tones; grass, reeds, hay or branches fixed in iron wire, etc.
3. Renew the camouflage in proper time: The grass and branches fade quickly and appear light and not dark on the photographs.
4. The position must not extend partly over one field and partly over another, as two fields are seldom of the same color. The furrows will be reproduced in the camouflage.
5. Camouflage materials, such as the sod removed and small trees, will be taken at a distance of at least three to four hundred meters from the position; place a dummy work at a sufficient distance in order that it does not reveal the true position.

(d) *Forms of Camouflage—*

1. Do not raise the height of the camouflage needlessly; the higher it is the more shadow it throws. Raise it by means of posts during the work; bring it down by day and lay it flat if possible; cover mainly the entries and exits.
2. Do not make a heap of the earth removed but scatter it immediately.
3. There must be no fresh cuts visible, as marked contrasts result from it between the light and dark surfaces, the latter appearing as deep shadows on the ground.
4. Avoid regular shapes and rectangular outlines.
5. Do not change natural shapes. Positions in fills and embankments must not change the form of the fill or embankment.
6. Use the roads, fills, embankments, slopes, sunken roads, edges of woods to greater extent. Deceive the enemy by false tracks ending in woods.

II. Main Instructions for Columns.

(a) *Resting columns, location and nature of halting-places—*

The most important thing is that the halting places be of irregular form.

1. It is best to distribute the columns irregularly under trees of gardens, avenues, roads and courtyards, even if not very dense.
2. The camouflage of wagons or artillery pieces by means of branches does not secure them from reconnaissance by airplanes, when the column is in the open on light colored ground, as for example, on dry roads. Shadows enlarge in a surprising manner.

3. In villages, keep close to the houses, walls, enclosures of gardens and hedges, but if possible, with irregular distribution. The best side is always the north side of houses, walls, etc., on account of the shadow.
4. In small courtyards, the wagons are lined up one beside the other and the tarpaulins joined in order to make a roof. This appears as a smooth and very natural surface on the photograph, which does not attract the enemy's attention.
5. Lessen the tracks, if possible. Do not widen the roads of approach uselessly. Follow the track. Mark out footpath, staking them out, if necessary, by wire.

(b) *Troops on foot, wagons and artillery columns on the march*—

1. Even at night make more use of tracks which are generally dark; the columns can then with difficulty be observed by airplanes; on the other hand, columns on roads which appear light can be seen even at night.
2. Infantry columns will be divided into small groups distributed in depths and advance along the shady side of roads.
3. When airplanes use light projectors at night keep in the shade of trees or buildings.

III. General Rule.

When surprised by airplanes either by day or by night use all natural shade provided by trees, embankments, houses, etc., and remain motionless.

By order of the General Commanding the Army,

Chief of Staff.

(Signed) FAUPEL,

Lieutenant Colonel.

A TECHNICAL DESCRIPTION OF THE BRITISH LIGHT RAILWAYS IN FRANCE.[1]

By

Lt. Col. B. W. Guppy,
Engineers.

The light railway lines operated by the 14th Engineers (Railway) comprised the "C" Section lines with headquarters at Boisleux au Mont, operated by Companies A, D, E and F under the direction of the A. D. L. R. III Army (North) and the "Back Area" lines with headquarters at Pozieres, operated by Companies B and C, under the direction at first of the A. D. L. R. III Army (North) and afterwards of the A. D. L. R. III Army (South). Each system contained approximately 50 miles of main line track exclusive of yards and sidings, but no comparison can be made of the work done by the two detachments on account of the great dissimilarity of the work required of them.

The C lines were built primarily to serve the front line. They were afterwards extended through "No man's land" as it existed prior to July 1st, 1916, for salvage operations and to form part of a through light railway line, approximately parallel to the front. After the offensive of March 21st, 1918, additional lines were rapidly constructed linking together the parts of the system then remaining in the hands of the British and making connection with broad gage railheads in the rear. Notably among these was the line built from Beaumetz le Loges through Fosseux railhead to Savy with a connection to Frevent formed by adding a third rail to an existing meter gage railway. The back area lines were used principally for hauling material salvaged from the Somme battlefield to the dumps at the broad gage railheads.

Lines in the forward area were located to avoid enemy observation as far as possible and long tangents were not used. Maximum grade for main line was 2½ per cent. On spur tracks, where absolutely necessary a maximum grade of 5 per cent was sometimes

[1]A Technical Description of the British Light Railways in France, Operated by the 14th Engineers (Railway), American Expeditionary Forces, from August 25th, 1917, to May 19th, 1918.

used. A minimum curve of 30 meters radius was used. When the track came in fabricated sections, it was made up in radii of 30, 50, 100 and 150 meters.

Back area lines consisted of lines built during the battle of the Somme with such additional lines as were found necessary to cover the territory to be salvaged. They gave direct connections between the various broad gage railheads.

TRACK CONSTRUCTION AND MAINTENANCE.

The details of track construction were changed at different times, but were generally as follows:

Gage, 60 cm.

The standard cross section of rail furnished by the British Government was: height, $2\frac{1}{2}$ inch; base, $2\frac{1}{2}$ inch; width of head, $1\frac{3}{8}$ inch; width of web, $\frac{1}{4}$ inch. This was furnished in three lengths $2\frac{1}{2}$, 5 and $7\frac{1}{2}$ meters. Weight, 20 pounds to the yard. Standard drilling for bolt holes $1\frac{3}{4}$ inches; $3\frac{1}{2}$ inches. There were no markings on rails as to date and place of manufacture, the quality of the rails varied, for the most part they were very soft. Quality deteriorated as the supply increased.

A few miles of the track consisted of light railway track which had been part of the lines of communication of the German Army when it occupied the area. This was also 20-pound rail, but of a different cross section; base $2\frac{1}{8}$ inches; height $2\frac{3}{4}$ inches; width of head 1 1/16 inches; width of web $\frac{1}{4}$ inch.

In forward areas and on a few side-tracks a rail of lighter weight (9 pounds to the yard) which had been laid by tramway companies for equipment moved by hand was connected to the 20-pound rail.

One type of splice only was used as follows: Length, 14 inches; height, $1\frac{5}{8}$ inches; thickness, 7/16 inch; four bolt-holes, 9/16 inch diameter; drill as above; inside fishplate had square hole, outside round hole. With some types of fabricated track there were no connections between rails except the clips on the ties. This track sometimes pulled apart.

Where steel ties were used a bolt and clip fastened the rail to the tie; where wooden ties were used spikes of the usual pattern were furnished; $\frac{1}{2}$-inch bolts, $2\frac{1}{4}$-inch underheads were used to secure fishplates. Switchstands, known as tumbler stands, consisted of a lever working in a block. Throw-lever was of $\frac{1}{2}$-inch

steel, 2½ inches wide at base, tapering to 1 inch wide at end; 27 inches long; counter-weight was 6 inches in diameter of 2¼-inch steel with adjustable screw. Where clearance between track would not permit switchstand being set at right angles to track, a ball crank connection was employed permitting lever to set parallel to track.

The head blocks on which the stands were set usually consisted of 3 by 10 inch plank—12 feet plus or minus long set on edge.

In May, 1918, tieplates about 6 inches square and ⅜ inch thick with spike holes were furnished for use on curves. Sufficient experience with the plates was not had to test their effectiveness, but undoubtedly many derailments which occurred from spreading track would have been avoided had tieplates been furnished sooner.

The original Decauville rail was riveted to the steel tie. The German rail was secured to the steel tie by a steel clip which lapped the base of rail and had four bolts.

The iron tie, the use of which was later discontinued, was made of soft pressed steel 3 feet long, about 3/16 inch thick, 7 inches plus or minus wide with a groove about ½ inch deep and 1 inch wide through the center. In portions of the road built in 1917, following the German withdrawal, these ties were placed on "trench boards"—that is, plank 3 by 10 inches, 6 to 7 feet in length.

There were two types of wood ties of the so-called Light Railway tie—4″×6″×4′, 6 inches, and the so-called meter gage tie, 6″×6″×6′, 0 inch.

The steel ties in German track were not grooved, but of a heavier material. The rigidity of these proved effective when trains were derailed and loaded cars ran for any distance on the ties.

Connections fabricated complete were divided into three parts for ease of handling: the switch, the lead, and the frog. Connections were of two classes—right hand or left hand. The connections were riveted to steel switch ties. Guard rails were also riveted to the switch ties and attached to the main rail by bolts through iron block or spreader.

The switch rails were 6 feet long, switch rail for connection was curved on radius of turnout from a point 3 feet back of switch point. The stock rail was offset to allow the point of the switch rail to be fully covered. The slides made into the iron ties furnished the moving surface for switch rail.

During the summer of 1917 the design of frogs was changed. Previous to that time the frog point was made up of two rails equally beveled and coming to the point, these points being riveted together. The design was superseded by a frog point made of two rails, one of which form the point, while the other was cut to a bevel joining main frog rail several inches back of the point, allowing point to be made of one continuous piece of steel. The former type required constant attention and frequent renewal and caused many derailments; the latter proved to have far greater life and durability. Main line frog rail was about 1 foot longer than switch frog rail. The point and wing rails of frog were curved for the siding.

Connection rod was joined to point of switches by a plate riveted to switch rails and fastened with cotter-pin bolt. None of the switches were adjustable, being made into standard throw by means of switch stands and tumbler.

Ballast consisted of chalk or sand obtained from pits along the right of way and slag or mine earth shipped from Northern France. Chalk ballast was used only in cases of necessity in the back areas. It proved very poor when subjected to heavy track in wet weather. The track under which it was placed required constant attention. The Air Service objected to its use because of the way in which it indicated location of the track to the enemy.

All usual tools used on standard track maintenance and construction were supplied. In addition to this we made up wooden paddles for tamping sand under ties; these implements proved very effective.

No signals were installed by this regiment. There were installed at three places on the new line built in May, 1918, a set of signals at broad gage diamonds, these being connected up with derails on the Light Railway only and were NOT interlocked to the Broad Gage signals.

In building track the amount of curvature was sacrificed to keep the amount of grading to the minimum. Principles governing practices in laying standard gage track were used in building new lines. In many cases track was laid on the ground where the surface was level enough to permit it, the uneven spots being taken up with ballast. On account of the light weight of the track it was unnecessary to use jacks to lift the track for ballast. Lining bars and wooden blocks served the purpose. Culverts made of corru-

gated iron were installed where necessary. Guard rails were used on every sharp curve. At highway crossings where the volume of traffic was great, the space between main line rails was filled with scrap rail laid 3 inches on center. Highway crossing signs were erected.

The practice of fabricating track and laying it in sections was discontinued when wooden ties were substituted for steel. In made-up sections four steel ties were used to 2½-meter rails. Where so-called meter gage ties were used on main line they were laid, as 1st, 2nd, 4th, 6th and 9th; the 3rd, 5th 7th and 8th being light railway ties to each 5-meter rail.

There were no springs in the switchstands furnished, and as a result, many derailments were caused by split switches. No method of locking switches was in practice and in a number of cases where the line passed through towns in which civilians still remained, trouble was had from mischievous children. While a great many derailments occurred the effect on the track so far as its maintenance was concerned was more or less negligible and the emergency crew which was always at hand was seldom called for derailments which were not caused by shell fire. Considerable trouble was experienced by tanks crossing the right-of-way regardless of the effect upon the railroad. Where the tanks had a manœuvring ground and where the route to the front was pre-determined, a so-called tank crossing was installed. This was built up in such a way that the tank itself did not come in contact with the track and much damage to the track was avoided by this simple device. In forward areas there was constant damage to track on account of shell fire. During the offensive of late March, 1918, the track was broken 17 times in one night, but throughout the entire time the 14th Engineers (Railway) maintained light railway track, no track was left unrepaired for more than two hours after the damage had been caused. In a great many instances a great deal of ingenuity had to be shown in order to convert material at hand into a suitable bed and track for ammunition trains but the emergency was invariably met, in one case by using a piece of 2 by 4 fence rail 10 feet long and ''jury rig'' so that no delay should be caused to parties waiting for the supply of ammunition. Bridges in forward areas were made from any available material, in many cases trees which had been felled by the Germans in their withdrawal were taken and thrown across the stream and used effectively as stringers.

MOTIVE POWER AND ROLLING STOCK.

Three types of locomotives were used in the C section lines. The following table shows the principal dimensions of these engines:

	Baldwin 4-6-0 Side Tank.	Hunslet 4-6-0 Side Tank.	Hudson 4-6-0 Side Tank.
Cylinders, diameter	9″	9½″	6½″
Cylinders, stroke	12″	12″	12″
Wheel forge, diameter	1¼″	1′6½″	
Wheel coupled, diameter	1′11½″	2″	1′11″
Fuel cap, cwts.	15.7	15	3.5
Water cap (gallons)	396	375	110
Diameter of band, external	2′9″	2′9″	2′1″
Length of boiler between tube plates	7′¾″	5′0″	5′8¾″
Tubes, number of	84	86	45
Tubes, extra, diameter	1¼″	1½″	1⅝″
Tubes, length	7′3″	3′2½″	3′10⅜″
Tubes, material	Brass	Brass	Steel
Tubes, heating surface square feet	231	168	108.5
Fire box, surface	23.5	37	17.5
Total, surface	254.5	205	136
Grates, area	5.6	3.95	3.25
Working pressure	178	160	160
Width, over-all	6′11″	6′3⅓″	5′8″
Height, over-all	9′3¼″	8′11½″	6′6″
Length, over-all			
Brakes	Steam & hand	Steam & hand	Hand
Fire box	Copper	Cu (Belpairs)	Copper
Valve seal	Walschaert	Walschaert	Walschaert
Weight, empty, tons	11.04	10.00	5.755
Weight, empty, pounds	24730	22602	12891
Weight, in working order, tons	14.50	14.05	6.8775
Weight, in working order, pounds	32480	31472	15428
Max. weight on a pair of wheels	3.46	3.5	2.3875
Max. weight per foot of wheel base	1.1918	1.08	1.653
Max. weight per foot run over buffers	.7431	.706	.4462
Max. weight on coupled wheels, tons	10.30	10.5	6.8875
Max. weight on coupled wheels, pounds	23251	23520	15428
Center of gravity, height	3′0″	2′10½″	2′7½″

Most of these engines were of the Baldwin type, and on account of our being more familiar with the boiler feed on these locomotives they were operated a little more successfully than either the Hunslet or Hudson engines, the latter engines being equipped with a boiler feed of unfamiliar design to our men, and one which quickly got out of order, and in such a way as to render repairs by the engineer impossible on the road. This, of course meant engine failures, and

in addition to this necessitated our repairmen familiarizing themselves with the repair and maintenance of two different types of boiler feeds.

During the month of October, 1917, the Hudson and Hunslet engines were withdrawn from service on the C Section lines, after which there was very little trouble with injectors. Owing to the poorly constructed track in the back area the use of Baldwin locomotive was limited to the line from Bapaume to Bazentine. It was necessary to use the lighter Hudson and Kerr-Stuart engines on the remainder of the lines.

On the lines close to the front gasoline tractors were employed on account of freedom from noise and smoke. Three types were used, as follows:

20 H. P. Simplex, 0—4—0, 4 cylinders;
40 H. P. Simplex, —4—0, 4 cylinders;
40 H. P. Petrol-Electric, 0—4—0, 4 cylinders, 1 generator, 2 motors.

The repair shops at Boisleux consisted of a small running repair shed, a small pit shed, which would hold two engines, a detached blacksmith shop, a detached storeroom and a detached tinsmith shed.

The tool equipment was of the most meagre kind, and consisted only of several vises, one or two hammers, some second hand files, and a makeshift power drill, the latter being put together and got into running condition entirely by our forces. This condition, of course, was a great handicap to the successful running repairs of locomotives, but under the circumstances our men adapted themselves to the conditions, and accomplished very creditable results.

The repair shop at Pozieres was no better equipped than the one at Boisleux, and much the same sort of work was done at both places. More extensive repairs, however, could be carried out at Pozieres on account of the proximity to the shops at Meault where any necessary lathe work could be done for us by German prisoners.

The extent of repairs made by our forces included all light running repairs, reducing of brasses, rolling of tubes, replacing of ferrels in tubes, and toward the end of our stay, the renewing of tubes up to 18, and the renewing of driving box brasses. The latter operation necessitated the dropping of wheels or jacking the

engines up before the removal of the boxes, and while greatly handicapped in the performance of this work, it was done, and quite successfully.

The direct effect of the water used in the boilers of these engines was the necessity of washing all boilers out at least once per week, whereas in the States our boilers were supposed to be washed out, in ordinarily good water districts, once per month. In washing out we found almost nothing in the boilers but a soft chalky sludge, which was easily removed, and did not attach itself to any great extent to either the tubes or sheets.

The tubes on all these engines were ferreled for the purpose of preventing leakage, and also tightened by means of driving the ferrel farther into the tube. This meant, of course, a little reduction in flue leakage, but the detriment to the locomotive by the ferreling of the tubes more than offset the advantage of ferreling. Ferreling the flues means increasing the diameter of the flue opening, allowing a smaller space for the passage of fire box gases, and also offers a greater opportunity for the blocking of flues.

The grates in these fireboxes were of the fixed type and could not be rocked for fire cleaning. This necessitated the cleaning of fires through the furnace doors, shoveling of ashes and clinkers out of the firebox, leaving the firebox door open much longer than would be necessary with rocking grates, consequently reducing the firebox temperature, causing leaky flues. If these engines could be equipped with rocking grates the advantage would more than offset the expense.

No comparative statement of efficiency of the different types of engines can be made as no test was ever made between two locomotives of different type. The Baldwin appeared to be the more efficient engine, especially when handled by an American crew. In fact the American crews got a good deal more out of all engines than our predecessors, this being due entirely to the American mechanical man's idea that a locomotive was built to haul cars for revenue, regardless of shopping or running repairs. Our men toward the last of our stay at Boisleux were handling at least 60 per cent greater load with one engine than had been done by those preceding us.

Cars in Use on the "C" Line.

A few ambulance cars were furnished for transporting wounded. All other cars furnished were of the following classes of freight cars:

Class A. 1 Truck (4 wheels);
Length of body, 6′ 0″; width, 4′ 0″;
Height of sides, 2′ 6″; space, 60 cubic feet;
Capacity, 2½ tons.

Class B. 1 Truck (4 wheels);
Length of body, 8′ 0″; width 4′ 0″;
Height of sides, 2′ 6″; space 80 cubic feet;
Capacity, 3½ tons.

Class C. 2 Trucks (8 wheels);
Length of body, 12′ 0″; width, 4′ 0″;
Height of sides, 2′ 6″; space, 120 cubic feet;
Capacity, 10 tons.

Class D. 2 Trucks (8 wheels), 4-Door type;
Length of body, 17′ 0″; width 5′ 0″, height of sides 2′ 0″;
Space, 120 cubic feet;
Capacity, 10 tons.

Class E. 2 Trucks (8 wheels), 2-Door type with well;
Height of body 17′ 0″, width 5′ 0″, height of sides 2′ 0″;
Length of well, 7′ 0″, width 5′ 0″, depth 1′ 6″;
Space, 225 cubic feet;
Capacity, 10 tons.

Class F. 2 Trucks (8 wheels), Stake Type with well;
Length 18′ 0″, width between stakes 5′ 3″;
Space in well, 55 cubic feet;
Capacity, 10 tons.

All of these cars were built of wood, with wooden floor, sides and under frames, some sides having doors, while others are straight and fixed depending on class. All cars were mounted upon detachable trucks, and the draw-bars were attached to these trucks. The trucks were either of wood or steel frames and each truck had two axles. The wheels were 14-foot diameter with 3½-inch flanged tread. There were also a few special cars with steel frames for moving artillery, pipe, long timbers, etc. All light repairs to these cars were made by a detachment of the 14th stationed first at Achiet le Grand and afterward at Fosseux. This detachment began work on September 18th, 1917.

The first work was to build the necessary outbuildings and make

repairs to captured German light railway cars, and to dismantling obsolete types of English cars. Work was also started on the erection of a workshop 16 by 38 feet and a blacksmith shop 15 by 20 feet. Tools for this work were drawn from the central light railway stores and from light railway repair train, consisting of a fairly good assortment of carpenter tools, and a limited supply of tools necessary for car repairs, consisting of jacks, wrenches, etc. The blacksmith shop being equipped with forge, screwing machine, bench vise and a fairly good assortment of blacksmith tools.

The light railway repair train was a well equipped machine shop in light railway box cars, consisting of two generating sets operated by gas engines, air compressor for air drill and hammer, drills, hack saws, emery wheel, grind stone, lathe and shaping machine, all motor driven. The drills and power back saw were particularly useful in the construction of steel framework on new cars.

A 1½-ton crane with a 15-foot radius was later received and erected, which was very useful in connection with the work of our repairing, being used instead of jacks for removing car bodies from trucks. The only tools taken from this regiment being a chest of carpenter tools from Company C.

The work of repairs to captured German cars was continued through the months of September, October and November, approximately thirty-five of these cars being put into serviceable condition. At the same time new cars similar to Class D cars used by the British Government were built, entirely from salvaged material. The iron and steel used in connection with the work was taken from an old German dump at Waincourt, and the lumber being worked up at a sawmill in Logeast Wood, from trees felled either by the Germans or for military purposes. These cars were 18 feet long and 6 feet wide, steel frame and mounted upon old French artillery trucks. Eight of these cars were put into service.

About the middle of November construction of ambulance cars for use in the light artillery was started upon original lines. 2nd Lieut. W. Murray in charge of the repair train and Lieut. Hayes working together upon the design. The first one constructed, while considered the very best possible for the transportation of the wounded, was thought to be too expensive, and was modified to a certain extent. This car was widened 18 inches to allow a convenient passageway through the center, and was equipped with hot and cold water and electric lights, and a door in each was installed.

The eight other cars constructed were not widened, and hot and cold water, electric lights and springs being omitted.

Experiments with a light rail car fitted with winding engine for balloons were made, and one car constructed but was not adopted.

In December, snow plows and flange diggers were constructed, one wooden plow and one steel plow, fitted upon an F-class car with flange diggers were built but were not used as there was not sufficient snow to make it necessary.

Sixty American Western Dump cars were assembled and eight American hand cars, the parts being shipped from Berguette Shops. Approximately eight gun carriages for handling 6 and 8-inch howitzers and 60-pounders on light railway cars were received, assembled and distributed to the 31st L. R. O. C. at Arras, 14th Engineers (Ry.) at Boisleux au Mont and the 13th Canadians at Achiet le Grand. Repairs were made on this equipment as required. During the latter part of January and throughout February, all repairs to light railway cars from the Third Army, Arras to Achiet le Grand were made. Salvage work, with the exception of construction of new cars of the D class, being discontinued.

During February, six sets of rail cars were fitted up, B class cars being used for this purpose. A bolster being fitted upon each car with end stakes. The two cars connected with a collapsible coupling, which would allow loading of 18 or 24-foot rails, this class of equipment being intended for construction work.

After the detachment was moved to Fosseux only light repairs to cars were made, no heavy work such as rebuilding cars was attempted. These light repairs consisted mainly of rebuilding broken trucks, repairing brakes, brake staffs and standards; straightening frame braces; overhauling woodwork such as floors, doors, sides and ends; replacing worn brake-shoes and brasses and also wheels. Only when a car had been in a wreck or had been damaged by shell fire was it necessary to rebuild the under frame work. As the draw-bar was attached to the trucks, these trucks were the principal item of repair.

The buildings and equipment consisted of a large shed for the car tracks and a smaller shed for a blacksmith shop. The principal equipment was a forge, anvil, drill press and in addition an assortment of hand wrenches, hammers and other such like tools. The B. E. F. have a small machine shop mounted upon light railway cars and this plant had a lathe, shaper, saw, drill presses, etc., all directly connected to electric motors, and whenever necessary

this equipment was available. Materials for these "light repairs" were carried in stock at a central storeroom and were drawn from this source. But, owing to the limited supply carried, it was more often necessary to make most of the parts used, especially woodwork which was cut and fitted from rough stock.

It is difficult to estimate the amount of work done by the detachment on the repairing of light railway cars. But the work done during the last twenty-one days in April, when conditions were somewhat unsettled, might be taken as an example; repairs were made on 83 cars, divided as follows:

Class C, 3 cars;
Class D, 58 cars;
Class E, 15 cars;
Class F, 7 cars.

Included in the above was the complete rebuilding of forty-seven trucks for the above cars.

The back area lines were furnished with very few of the standard cars for salvage work. The cars first furnished were of the so-called Wooden Pillbox type, and so designated by reason of their smallness. The average dimensions were $4' \times 5' \times 2'$. For journal bearings small hardwood blocks set in iron castings attached to the body served in the place of the customary brasses. Of these there were approximately 110, of which about 30 were in service on taking over the road, the remainder being piled in the yard awaiting repairs. These cars, however, were not adapted for hauling salvage, as it included long timber and rails, etc. As it was impossible to obtain any long cars from the A. D. L. R., it was decided to construct some long flat cars. At different point out on the line numerous steel truck frames had been left by the Germans which had been used by them as a single truck car. These were all gathered in, repaired and reinforced in many places, using two of these trucks under each car, making a double-truck car. The car bodies were of the two and three-sill type checked on the ends and cut-in for the bolsters with ½ by 7 inch bolts countersunk and placed diagonally. Iron fish plates with four $\frac{7}{8}'' \times 4'\ 6''$ cross rods were put in for additional strength. The floor was made up of planks varying in size from 2 by 6 inches to 3 by 8 inches. For center plates $\frac{1}{2}'' \times 10'' \times 18''$ armorplate steel with four holes for wood screws was used. The friction plates were occasionally made of hard wood, but of iron when such was available. From September

10, 1917, to February, 1918, 20 such flat cars were built, varying in length from 13 feet 6 inches to 19 feet, in addition to all running repairs on those already placed in service and the numerous so-called Pill Boxes, which had to be repaired from the very start. Next three steel flat cars were constructed. The trucks used on the steel flats were salvaged gun carriage trucks. For the car frame channel irons 7 inches by 20 feet were used. The plans called for a 20-foot frame, the centers 14 feet 6 inches on pivot bolsters belonging to the trucks, beams to be clamped and also riveted with two cross or horizontal irons placed 4 feet, 10 inches on centers. No channel irons were available, so I-beams were used for the ends and so put that the web came flush with the longitudinal beams. In order to rivet and clamp them onto the bolster four 11/16-inch channels were cut in web of main frame, and the following holes drilled—four 1-1/16″—eight 11/16″ in each bolster, and riveted. All told, approximately 110 holes were drilled in each car body, 55 rivets, all hand made, of ordinary round iron. Two 1-inch tie-rods running across along each side of bolsters were used to strengthen the frame. These cars had a carrying capacity of 10 tons.

On account of the shortage of water and water stations on some parts of the back area lines it was necessary for engines to run a considerable distance light for water. To overcome this several 400-gallon water tanks were mounted on single steel trucks. These tanks were filled with water at the home terminal and taken along next to engine each morning as an extra supply to be used during the day. This overcame many long delays of engines running light after water, an ordinary trench hand pump being used to transfer the water into water tank on engine. Later on, when cold weather set in and water supply at Pozieres froze up it became necessary to haul water from Bazentin for all purposes at Pozieres, including Salvage Dump. These water trucks were immediately pressed into service, while others were being fitted up to handle the enormous amount of water consumed.

When any material was required for repairs or new work, such as boards, plank, 2 by 4-inch studding, square timber, round iron, bar iron, sheet iron plates, tool steel, lining bars and track tools it was necessary to salvage them as they could not be procured from any other source.

WATER SUPPLY.

The various sources of supply of water included brooks or streams, if they were available, army or corps pipe lines, if they were located where they could be tapped without laying too long a line of pipe to reach railways; old French deep wells, if they had an abundant supply of water and were located near enough to light railways to warrant their use; bored or driven wells where it was necessary to go to the expense of installing them; hand dug wells, where the known water level was near enough to the surface to make them practicable, providing no easier method of getting water was available; shell holes or any holes beside the track that fill up with water, the engines being equipped with suction hose and apparatus; and light railway water tank cars filled at some water point and hauled to some other point where needed.

Of these sources of supply either a stream or any army or corps pipe line was most favorable, if located near the railway because of the small amount of material and equipment required and the little labor usually needed to install a water point of this kind.

The water from a stream was usually pumped by a Merriweather pump into an elevated tank located beside the railway. At water points that were but little used; however, a good hand pump was used. If the water point was only temporary the Merriweather was used to pump the water from the stream directly into the locomotive tank, thus eliminating the elevated tank, also in some cases the locomotive suction hose could be used to take the water directly from the stream. This latter practice, however, was unsatisfactory, as too much time was generally used in filling the locomotive tank.

If an army or corps pipe line was used the pipe was tapped and the water piped into an elevated tank placed beside the railway. Usually, an army or corps pipe line had pressure enough to run the water into an elevated tank without the use of a pump. If a pump was needed a Merriweather placed beside the army or corps pipe line was the most desirable pump for this purpose that we used.

There were some excellent water points supplied from old deep French wells. It was sometimes difficult, however, to get permission to use these wells. If they were used, of course it was necessary that they had an abundant supply of water. These wells were generally very deep, usually ranging in depth from 75 to 225 feet, and about 6 or 8 feet in diameter. A deep-well pump was of course

necessary for this style of well, this is to pump the water into an elevated tank beside the light railway.

We had wells driven at points where it was necessary to have water, where it was impossible to locate any other source of supply at that point. These wells, as with the old deep wells, usually ranged from 75 to 250 feet in depth. The same style of pump, apparatus and power being used. When these wells were driven, they were placed in a convenient locality to eliminate a long pipe to the elevated supply tank. They were usually made 6 inches in diameter and cased with 6-inch pipe if necessary. If they were drilled through flint or hard chalk, it was not necessary to have the casing. If the chalk was soft and inclined to crumble, the casing was necessary the same as when drilling in clay, sand, etc. The casing in the lower part of the well was perforated with holes about ¼-inch in diameter and about 3 or 4 inches apart, this to let a supply of water in from the sides of the wall. When the well was being driven it was occasionally tested, this to determine the depth necessary to get the desired supply. The type of well drilling machine used by us for this work was an ordinary steam driven well driller with about 25-foot boom, the well driller being mounted on wheels with a separate horizontal boiler, about twenty-five horsepower, also mounted on wheels. This made an easy matter to load the well drilling machine and the boiler, each on a 6 or 8 inch light railway gun carriage for transportation.

We also dug wells by hand beside the light railway for a water supply when it was known that a plentiful supply could be obtained by digging from 25 to 40 feet in depth. These wells were usually dug and cribbed about 7 or 8 feet square, the same type of pump and apparatus being used as with the deep wells. It was not often, however, that a good supply of water could be obtained at that depth in territory in which we operated.

In some localities while constructing track, and until better water points could be installed, we found plenty of shell holes filled with water and conveniently located to enable us to supply our locomotive by use of locomotive suction hose. This being especially so in winter or spring season.

At points where it was necessary to have water and where it could not be procured otherwise, we supplied water by use of light railway water tank cars. These tank cars were made up of ordinary tanks placed on a light railway car platform and trucks. The tank being constructed of 3/16-inch galvanized iron, suitably

braced, 17 feet 6 inches long, 5 feet wide and 2 feet 9 inches high with capacity of approximately 1,800 gallons, fitted with a manhole 14 inches in diameter on top near each end. The water was conveyed to the locomotive either by locomotive suction hose or by hand pump located on top of each car. These tank cars were also used quite extensively to deliver water to batteries, camps, etc., along the line of light railway, a water train usually being run every night for this purpose.

The Merriweather pump which we used is a small steam pump, mounted on the side of a small upright water-tube boiler, and is very desirable on account of its compact and light construction, making it very easy to move around and set up. It also does excellent work and needs very little attention or repair. It cannot be used, however, to lift water from wells, etc., to any great extent, as it will only lift successfully about 20 feet. It therefore must be confined to the service of forcing water when the source of supply is nearly level with the pump, such as taking from streams or army or corps pipe lines when these pipe lines have not the required force to flow to our elevated tank. This pump will elevate water several hundred feet and is an ideal pump for light railway service when the source of supply is within reach.

When the supply is from an old French well, a bored well or any well over 20 feet in depth, a deep-well pump is used. The types most used are either Duke & Ockenden, or Potter, 1,000 gallons per hour capacity. They are similar in design, each having a pulley shaft geared to a crankshaft, the crankshaft operating a connecting rod connected to a rod which extends to the bottom of and is inside of a 4-inch pipe line. This 4-inch pipe line extends from the base of the pump to within a few feet of the bottom of the well, if it be a 6-inch bored well, or about to the water level if it be an old French deep well or one similar. A brass cylinder, 3¾ inches inside diameter, in which the reciprocating valve operates is connected to the bottom of the 4-inch pipe line, the valve being connected to the rod which extends down inside the 4-inch pipe, from the pump. The bottom of the brass cylinder is fitted with a check valve and, if used in an old deep well and placed just above the water level, has a 2½-inch suction pipe extending down into the water a few feet. If the well be a few feet in diameter this barrel is placed just above the water level to make it possible to easily make repairs, if necessary. If installed in a 6-inch bored well, of course, it is necessary to make the apparatus up at the top

and lower it complete. The well-drilling machine can be used to excellent advantage in doing this or if the well-drilling machine be moved away a staunch tripod with chain block and falls will do the job. These pumps are generally driven by gasoline or kerosene power. The Potter Junior 6-Horse or the Jappy 6-Horse are the type of gasoline engines used most in this service. The Blackstone kerosene engine is also an excellent engine for this work, specially if there is a large quantity of water to be pumped, as it is much cheaper to operate than the gasoline type. If the pump is only operated for a few minutes at a time, but is started up several times during the day to fill the elevated tank, a gasoline engine is more favorable as it is started up much more quickly and easily than the Blackstone.

The supply pipe line from the pump or army or corps pipe line to the elevated tank was usually of 2-inch or 2½-inch pipe, the 2½-inch pipe being a very desirable size. In some cases 4-inch pipe was used; this practice, however, seems to be wasteful, as a 2½-inch pipe will easily convey all the water the Merriweather or a 1,000-gallon-an-hour deep well pump will throw.

The elevated tanks which are placed beside the light railway for storage were of several different types. A much-used type was a tank 8 feet square, 4 feet high, constructed of 3/16-inch galvanized iron suitably braced, this tank having a capacity of approximately 1,900 gallons. Another type which was used quite extensively is a sectional tank, 8 feet square, 4 feet high, made up of sections of ⅜-inch iron, each section being 4 feet square. These sections were bolted together with ½-inch bolts, 4 inches apart. It required four sections for the bottom of each tank and two sections on each of the four sides. This tank also has a capacity of approximately 1,900 gallons. A few of these sectional tanks, larger in size, were also used, each side being made up of four sections and each end of three sections, these tanks having a capacity of approximately 5,000 gallons. This larger style of tank was used at some of the largest watering points. Another type of tank used was a cylindrical design, 4 feet in diameter and 4½ feet high, this tank being constructed of ¼-inch iron.

The elevated tank was usually placed on a stand apout 9 or 10 feet above the rail. This stand was usually made up of suitable wood posts with mud sills and top sills to match, and braced in a substantial manner. At some points we found tanks elevated on

cribs made up of ties; this, however, seems to be a wasteful practice, as much less lumber will be used in making a stand constructed of posts, etc. Where it was possible to do so it was usually planned to locate the elevated tank between a side track and the main line, this making it possible to supply engines on either side. The water was conveyed to the engines through a 4-inch gate-valve and hose placed under either side of the tank when the tank was located in this manner. It was also generally planned to water engines on the other end of the siding, the water being conveyed to the other end of the siding through a 4-inch pipe line connected to the bottom of the tank and connected to a standpipe located between main line and the siding at the other end. This pipe was made up of 4-inch pipe, a 4-inch gate valve located about 4½ inches from the ground, and a hose from the top of standpipe long enough to reach into locomotive tanks. The standpipe was usually made up with a quarter bend and elbow at the top, this allowing the hose to hang straight down without kinking when not in use. The top of the standpipe should be about 7½ or 8 feet above the rail. The clearance from a standpipe or tank to the nearest rail should be about 4½ feet.

At some of the larger watering points or at terminals, where a larger water system was required, several standpipes were sometimes supplied through 4-inch pipe line, from a single elevated tank. We had as many as eight standpipes supplied from one tank. In a system of this size, a 5,000-gallon tank is necessary. Several water systems of this type were constructed by us, as it was desired to run lateral traffic trains in fleets, the several standpipes being so located as to supply several engines, each with a train with water at the same time.

To prevent trouble from freezing in winter, all pipe lines should be buried at 2½ feet under ground, and all lines brought up into elevated tanks so that they can be easily housed in beneath the tank. A stove placed in this house beneath the tank will keep all the pipes, as well as the tank, from freezing. Standpipes should all be boxed in and packed with sawdust, hay or some such material. It is very important that all pipes and tanks be fixed up in this manner before cold weather sets, this to insure a good water system throughout the winter.

The tools used by this water construction gang consist of 4-inch

pipe dies and stock, 2 or 2½ inch pipe dies and stock, suitable pipe-cutters, two or more 4-foot chain tongs, two or more 3-foot chain tongs, two 2-foot chain tongs, two or more 18-inch stillson wrenches, breast drill, suitable hammer and chisels, suitable carpenter tools for building tank stands, pipe vise, the necessary shovels, picks, ropes, etc., and a well-drilling machine. Also monkey wrenches and other small tools.

A light-railway box-car fitted up with all the required tools, work benches, etc., and so constructed that it can be locked, is very desirable if a pipe-fitting gang is to follow up light-railway pipe work.

OPERATION OF THE C-SECTION LINES.

Operating Miles.

While headquarters were at Boisleux au Mont, the maximum miles of main line operated were fifty (50) miles; the Western limits being Beaumetz and Euston Dump; the eastern limits being Wancourt and Cuckoo Dump; the southern limit St. Ledger Junction, and the northern limit the junction of the Arras section at C-11.

There is no record of the mileage of side-tracks or yard-tracks, which, however, were considerable. In addition, trains operated by our forces ran to the north as far as Arras and to the south as far as Croisilles and Mory and into Achiet le Grand.

Control Board.

The English system which was turned over to us was as follows:

The Central Control, located at the A. D. L. R's office had charge of car and power distribution as between sections and the transmission of orders to the districts.

The District Control had a board which was substantially a graphical outline of the tracks, with runways along which were slide hooks. Attached to the hooks were the engine slips on which was noted the engine, engineer, conductor and consist of train with contents of cars. From these slips were figured the engine mileage. As the trains moved along the road the hooks were moved on the board. At each station on the board was a small tin box in which could be inserted the car slips, giving the car number, contents, weight, point loaded, point unloaded, times, etc. The box was divided into two parts for loaded and empty cars. A wagon sheet was also made out for each car, giving the car number,

contents, weight and points between which car was moved, with the times. From this sheet the Central Control figured the tons and ton-miles handled. The board also showed at a glance the location of all empty and loaded cars, so that movement of empty cars to points where they were needed for loads could be made in the most expeditious manner and the holding of cars under load for an excessive period of time could be checked and investigated.

Under the English system a train on arriving at a control box would request District Control for orders, which meant the train stopped at every control box. As we had competent and qualified railroad men, this system seemed slow and awkward and the District Control was changed into a dispatcher's office, keeping the outline of the English system. Standard train sheets were introduced and orders for movement of trains came direct from the District Control to the control boxes, so if the line was clear the trains need not stop. Orders for traffic as given out by Central Control were entered in a book in numerical order and entry made as to the time orders were placed and when they had been completed.

The English system of control boxes was made as a fool-proof system for men without previous railroad experience, and bearing this in mind it had very good points.

Control Boxes.

Control boxes were located with reference to existing sidings on junction points. In the control area the average number of control boxes was about one per mile. Control boxes were built of corrugated iron or lumber, if available, and in the forward areas telephones were in dugouts. Controlmen lived at the control box and there were two men to a box. The telephones furnished were rather a primitive type, the wall set consisting of a generating magneto and one pair of bells and primary batteries. The phones furnished are not used in England now.

The other type was a trench telephone, containing the same apparatus but compact in a wooden box about 1 foot square. Open wires are run as far as shell-fire will permit, where cable is substituted. The wire used was bronze wire, 40 pounds to the mile and iron, 70 pounds to the mile. The cable was the Army type, D-5 cable, single, which consists of one strand of copper wire with several strands of iron wire wound around it and insulated and braided. There was one or more circuits, depending on the num-

ber of instruments for the control boxes, and then a conversation line to the more important points handled through a telephone exchange.

Operating Forces and Organization.

Approximately three hundred (300) men were employed on operating, of whom, roughly speaking, one-sixth were employed in the District Control and control boxes, one-sixth as yardmen and switchmen and miscellaneous traffic duties, one-sixth locomotive maintenance and repair and the remainder train and engine crews.

Organization, one officer in general charge with an adjutant; one officer in charge of locomotives, one in charge of controls and dispatching trains, one in charge of traffic and one in charge of railway stores. Other officers if available were assigned as assistants.

Master Engineers and Sergeants acted as engine-house foremen, traveling engineers, trainmasters, and other duties of a more or less supervisory nature. It was not unusual, however, to see a sergeant running an engine or a tractor. It was very essential to have the most competent N. C. O's having general supervision over the railroad and dumps.

Classes of Traffic.

The following are the classes of traffic: Ammunition, Rations, Personnel, Light Railway Material, Light Railway Ballast, Royal Engineer Stores, Salvage, Roadstone Gravel, All Other Traffic.

Generally speaking, ammunition had priority, but the priority of other traffic was determined from day to day by the Corps Light Railway Officer.

Traffic.

So far as possible every endeavor was made to operate regular trains. Ration trains from railhead to dumps and from dumps to forward area were dispatched at regular times each day. In fact it was possible at one time to issue a time-table covering most of the train service. About thirty crews were used a day on an average. As an illustration of the traffic density, over the stretch between C-102-A and Henin Junction there were on quite a few days more than eighty train movements.

Light Railway Operating Rules are given in Appendix I. Hand and lamp signals prescribed in this order were not followed in accordance with the order, American practice prevailing.

As a rule we operated heavier trains than the British, on one

occasion twenty-seven empty cars were handled from Mercatel to Boisleux by one engine and on another occasion seventeen cars of ammunition were handled from St. Ledger Junction to Mercatel over severe grades with two engines on ahead and one behind. Double-heading was done, but was risky on the light track. The main flow of traffic was, of course, from the rear to the front. Ammunition, rations, and Royal Engineer Stores were handled to the forward areas, after dark, from the divisional dumps. In certain cases the entire haul was performed by tractors, in other cases the traffic was hauled in daylight by steam as far as possible and then worked by tractors after dark.

Water deliveries were made to all persons desiring water and for a considerable period we were handling all of the rations and water for the front line troops, and practically all of the ammunition to the batteries on our front. Battery locations were furnished us by the Corps and N. C. O's. had charge of certain sections and were responsible for knowing the location of batteries and units, and seeing that deliveries were made. Cartridge cases, empty boxes and other salvage material was handled from the front to the dumps. Considerable work was also performed in salvaging on the old Somme battlefield.

Operating Statistics.

Statistics were made up in the Central Control office. Complete operating statistics in the Third Army North for three weeks which may be taken as typical of the whole are given in Appendix II.

Operating of Back Area Lines.

The back area lines were operated under the rules given in Appendix I. Unfortunately all operating statistics were destroyed during the retreat, and exact data covering operations cannot be given. The cost of moving material on the back area line, however, was much in excess of the cost of work on the forward area lines. This was due both to the nature of the work and the lack of sufficient cars. The Hindoo and Chinese labor used for loading and unloading material was not very efficient and an excessive amount of time was lost in waiting on the labor parties. It was only by the closest cooperation between the operating and salvage officers that any approach to the efficiency could be obtained. The average daily tonnage was 600, the maximum 1,100. Most of the cars were hauled light in one direction, but every opportunity was taken to re-

duce the light movements to a minimum. The maximum of efficiency was reached in February and March during the reconstruction of the highway La Boiselle-Bazentine-Le Tansloy, when special cars and power were assigned to the work. Cars used to haul road stone from Pozieres stone siding to Bazentine were brought back loaded with salvage material for Bazentine. Cars carrying road timber from Bapaume dump to Waterlot Junction were loaded with salvage at Longeval and hauled to Trones dump, where they were loaded with road timber and returned to Waterlot Junction. When unloaded they were hauled empty to Bazentine and loaded with salvage for Pozieres. At Pozieres they were loaded with mine timber for the front and returned to Bapaume the same day as received. For this special work we were furnished several gasoline tractors, and it was very gratifying to find that we were held up as a model to the other operating companies in the area, as we were getting two to three times as much mileage per gallon of gasoline, which showed that when conditions were at all comparable we could show our efficiency. Similarly, while coal consumption per ton-mile of the C lines was higher than that of neighboring operating companies, the consumption per ton-mile was less, showing an economy in operation.

General Remarks.

The British system of light railways was constructed with the object of:

(*a*) The carriage of ammunition to heavy guns, batteries and troops;
(*b*) The carriage of R. E. stores to the forward dumps;
(*c*) The carriage of road material;
(*d*) The carriage of wounded men from the trenches to the clearing stations;
(*e*) The transportation of troops;
(*f*) The distribution of coal and rations;
(*g*) The carriage of timber for firewood;
(*h*) Salvage operations.

The system was designed to connect the broad gage railheads with the front. Unfortunately there had not been provided sufficient lines to the rear to be used in case of a retreat, hence much rolling stock was lost during the March offensive. When the battle started on March 21st all traffic in the light railway except that in

ammunition, water and wounded was stopped and recourse had to lorry, limber and horse transportation for handling rations, R. E. Stores, etc.

It would seem that light railways are of most use in a war of position. In a retreat they are rapidly put out of action and in an advance it is of more advantage to advance broad gage railheads as rapidly as practicable, depending on lorries and horse transportation for forward distribution, saving the additional handling required in loading and unloading the narrow gage cars.

APPENDIX I.

Light Railway Operating Rules and Signals.

These rules are laid down as guiding principles for the staff of Light Railways and refer to working under normal conditions. A. D. L. R's will issue such additional instructions as local circumstances may require. Any departure from these rules will be regarded as a breach of orders.

All concerned must make themselves thoroughly conversant with the standard Signals and with these and any rules issued by A. D. L. R's.

Under abnormal conditions such as shell fire sufficiently severe to dislocate traffic, the Officer or senior N. C. O. on the spot will make the best arrangements possible for the movement of trains.

Learn road. 1. Running staff must take the first opportunity of making themselves acquainted with the road over which they are required to run and with the position of Control Posts.

Attention to hand signals. 2. All men working trains must keep a sharp lookout for signals.

Passing control posts. 3. Under no circumstances must any trains pass a Control Post without receiving either a hand signal or verbal authority.

Manning of points. 4. Points at stations and Controlled Sidings will be operated by Yard and Control Staff. Points at uncontrolled sidings will be operated by the guard.

Correct setting.

5. The Train Crew must satisfy themselves that all points, both facing and trailing, are correctly set before engines or trains are run over them. Under no circumstances may trailing points be run through.

Guard's responsibility for train.

6. The Guard is in charge of the train and is responsible for seeing that no unauthorized person travels thereon.

Brakesman's duties.

7. The Brakeman works under the orders of the Guard.

Guard's responsibility for train.

8. The Guard must satisfy himself that the wagons on his train are not improperly loaded, are labeled and properly coupled together and that the brakes are in working order.

Guard's responsibility for train.

9. The Guard is responsible for the general safety of his train and for giving the driver the assistance of the brake when necessary. Also when the train is being propelled for keeping a lookout and for warning the driver when occasion arises.

Guard's responsibility for train.

10. The Guard must, whenever possible, ride at the front end of the rear wagon when a train is being pulled so that he may be in a position to apply the brakes on two wagons as necessary. When the train is being propelled he must ride at the front end of the leading wagon, so that he may be able to keep a good lookout. If there is a second brakesman on the train he will ride near the center of the train and be ready to assist with the brakes.

Smoking, when prohibited.

11. Smoking is strictly prohibited on ammunition trains or in the neighborhood of dumps.

Fly shunting prohibited.

12. Flying shunts are prohibited, but loose shunting may be carried out if necessary, provided proper precautions are observed.

Wagons on running lines not to be unattended.

13. Wagons must under no circumstances be left unattached on running lines without special authority.

Fires.

14. The staff must keep a sharp lookout for fires, which may be caused by sparks on the train or on dumps by the line side, and adopt means to extinguish same.

Protection of trains.

15. In the event of a train being brought to a stand in a section during the night from any cause, the Guard must immediately arrange to protect his train by placing a red light in the rear of his train, a reasonable distance from the last vehicle.

Failure of engine.

16. In the event of failure of engine or derailment likely to cause delay of 30 minutes, or if assistance is required, the Fireman (or where there is a brakesman, the brakesman) or, in the case of a tractor, the tractor driver, must proceed to the nearest control post and communicate with District Control.

Failure of telephone.

17. In the event of failure of telephone between Control Post Trains will, during daylight, be instructed to proceed with caution; during night the Guard will walk in front of his train carrying a red light. Up—that is, loaded traffic, will have preference.

Duties of.

18. All accidents, derailments or unusual occurrences must be reported to District Control and to the O. C. of the Company.

Duties of.

19. The driver is responsible for the general good condition and safety of his engine.

20. The driver must maintain a reasonable speed, taking into consideration the condition of the track, precaution orders, etc., the crossings over which he has to pass, and the distance over which a clear view of the track ahead can be obtained.

21. The driver must keep a good lookout for dumps and use every possible precaution against emission of sparks while passing same.

22. He must use every means in his power to avoid attracting the attention of the enemy in any way, especially by the emission of smoke or sparks in areas under observation. Efforts should be be made to avoid, as far as possible, the necessity for firing or opening the fire-hole door while under observation.

23. When crossing public roads or railway lines the driver must keep a very careful lookout not only for traffic but for signals, and give warning of his approach by one long blast on the whistle.

24. The Driver is responsible that no unauthorized person shall ride on his engine. The authorized persons are: The Train Crew and Officers or N. C. O's in the performance of their duty.

25. The Fireman must act under instructions from his driver. He must assist the driver in every way possible, and as well as helping the Driver in keeping a lookout is especially responsible for keeping the engine in steam and water.

Whistles Applying to Drivers and Guards.

1 short whistle------------- Call for brakes;
2 short whistles------------ Hove forward or release brakes;
3 short whistles------------- Hove back;
1 long whistle-------------- Warning for level crossing;
A series of short whistles--- DANGER, STOP!

Hand Signals.

RIGHT AWAY -- During the daylight hand waved slowly from side to side, the arm extended above the head. At night a white or green light similarly waved.

STOP --------- During daylight one or both arms held steadily above the head. At night a red light held steadily or a white light moved up and down to the full extent of the arm.

SLOW DOWN--- During the daylight one or both hands extended to the side and moved slowly up and down. At night a white or green light waved similarly.

GO FORWARD___(That is, away from the man giving the signal.) During daylight arm swinging smartly below the shoulder in vertical plane as in underhand bowling. At night a white or green light similarly swung.

COME BACK___(That is, towards the man giving the signal.) During the daylight arm swung smartly across the body. At night a white or green light similarly swung.

Appendix No. 2, Operating Statistics Light Railway III Army (N).

	January-February—Week ending—		
	Jan. 25.	*Feb. 7th.*	*Feb. 1st.*
A. Daily Tonnage Chart—			
(1) Total daily tonnage (Army Area)___	________	________	________
(2) Daily tonnage, B Section__________	________	________	________
(3) Daily tonnage, C Section__________	________	________	________
(4) Daily tonnage, X Section__________	________	________	________
B. Weekly Traffic Chart—			
(1) Total weekly tonnage (Army Area)_	26531	22949	25263
(2) Weekly tonnage, B Section_________	9985	8866	9262
(3) Weekly Tonnage, C Section_________	9320	6847	9020
(4) Weekly Tonnage, X Section_________	7220	5817	6980
(5) Total weekly ton-miles (Army Area)	144167	156558	221121
(6) Weekly ton-miles, B Section____.____	48395	37046	59290
(7) Weekly ton-miles, C Section_________	58117	83947	97453
(8) Weekly ton-miles, X Section________	37675	35565	64378
(9) Total loaded wagon trips (Army Area)_	4565	3818	4409
(10) Loaded wagon trips, B Section______	1586	1526	1614
(11) Loaded wagon trips, C Section______	1627	1136	1465
(12) Loaded wagon trips, X Section______	1352	1156	1329
(13) Total loaded wagon-miles (Army Area)	24281	20359	24797
(14) Loaded wagon-miles, B Section_______	7983	6781	7985
(15) Loaded wagon miles, C Section______	9506	7562	9185
(16) Loaded wagon-miles, X Section______	6792	6016	7717
C. Weekly Loco Coal Consumption Chart—			
(1) Total coal used (Army Area)________	221.5	204.4	213.05
(2) Coal used, B Section_______________	59.6	45.4	51.8
(3) Coal used, C Section_______________	85.25	88.2	91.8
(4) Coal used, X Section_______________	76.65	70.6	69.4

Appendix No. 2, Operating Statistics Light Railway III Army (N).

	January-February— Week ending—		
	Jan. 25.	Feb. 1st.	Feb. 7th.
(5) Total loco miles (Army Area)	10530	8174	9608
(6) Loco miles, B Section	3035	2608	2972
(7) Total loco miles, C Section	3876	5102	3847
(8) Total loco miles, X Section	3519	3004	2789
(9) Lbs. coal per loco mile (Army Area)	47.1	52.5	48
(10) Lbs. coal per loco mile, B Section	44	39	38
(11) Lbs. coal per loco mile, C Section	48	64	53
(12) Lbs. coal per loco mile, X Section	48.7	52	55
(13) Lbs. coal per gross ton mile (Army Area)	3.4	3	2.7
(14) Lbs. coal per gross ton mile B section	2.7	2.7	2.9
(15) Lbs. coal per gross ton mile C section	3.2	2.3	2.2
(16) Lbs. coal per gross ton mile X section	4.4	4.4	3.3
(17) Lbs. coal per loco hour (Army Area)	139	140.8	127.9
(18) Lbs. coal per loco hour B section	116	104.6	110.1
(19) Lbs. coal per loco hour C section	145	165.4	132.8
(20) Lbs. coal per loco hour X section	155	145.7	123.1
D. Weekly Loco Oil Consumption Chart—			
(1) Pts. cyl. oil per 100 mls (Army Area)	3.1	3.8	2.8
(2) Pts. cyl. oil per 100 mls B section	2.47	2.7	2.3
(3) Pts. cyl. oil per 100 mls C section	2.96	4.3	1.9
(4) Pts. cyl. oil per 100 mls X section	3.2	4.3	4.9
(5) Pts. eng. oil per 100 mls (Army Area)	3.5	3.8	3.2
(6) Pts. eng. oil per 100 mls B section	2.94	2.7	2.4
(7) Pts. eng. oil per 100 mls C section	3.32	4.3	3.4
(8) Pts. eng. oil per 100 mls X section		4.0	4.0
E. Locomotive Performance—			
(1) Total loco hours (Army Area)	3505	3252	3864
(2) Loco hours B section	1145	969	1053
(3) Loco hours C section	1317	1197	1548
(4) Loco hours X section	1103	1086	1263
(5) Total loco standing time	--------	--------	--------
(6) Total loco standing B section	--------	--------	--------
(7) Total loco standing C section	--------	--------	--------
(8) Total loco standing X section	--------	--------	--------

Appendix No. 2, Operating Statistics Light Railway III Army (N).

	January-February— Week ending—		
	Jan. 25.	*Feb. 1st.*	*Feb. 7th.*
(9) Loco mls per loco hour (Army Area)	3	2.7	2.5
(10) Loco mls per loco hour B section	2.7	2.7	2.8
(11) Loco mls per loco hour C section	2.9	2.6	2.5
(12) Loco mls per loco hour X section	3.2	2.8	2.2
(13) Av. gr. ton mls per loco per day (Army Area)	841	559	670
(14) Av. gr. ton mls per loco per day B section	838	352	633
(15) Av. gr. ton mls per loco per day C section	1092	799	926
(16) Av. gr. ton mls per loco day X section	611	338	461
(17) Loaded wag. mls per loco hour (Army Area)	526	4.6	4.9
(18) Loaded wag. mls per loco hour B section	4.4	3.7	4.6
(19) Loaded wag. mls per loco hour C section	7.4	6.4	5.8
(20) Loaded wag. mls per loco hour X section	4.7	1.3	4.8
(21) Av. loco train load (Army Area)	27.3	28.3	29.1
(22) Av. loco train load B section	24.9	21.0	21.0
(23) Av. loco train load C section	38.0	45.0	38.6
(24) Av. loco train load X section	17.0	15.0	25.5
(25) No. of loco under repairs (Army Area)	9	8	4
(26) No. of loco under repairs B section	3	4	2
(27) No. of loco under repairs C section	3	2	1
(28) No. of loco under repairs X section	3	2	1
(29) No. of loco in steam per day (Army Area)	33	40	38
(30) No. of loco in steam per day B section	9	10	8
(31) No. of loco in steam per day C section	12	15	14
(32) No. of loco in steam per day X section	12	15	18
(33) Mls per loco in steam per day (Army Area)	45.5	32	38
(34) Mls per loco in steam per day B section	48.0	37	47
(35) Mls per loco in steam per day C section	47	29	39
(36) Mls per loco in steam per day X section	42	28	26

Appendix No. 2, Operating Statistics Light Railway III Army (N).

	January-February—Week ending—		
	Jan. 25.	*Feb. 1st.*	*Feb. 7th.*
F. Weekly Tractor Performance and Consumption Chart—			
(1) Total Tractor hours (Army Area)	2324	2183	3780
(2) Total Tractor hours B section	892	913	1607
(3) Total Tractor hours C section	457	412	580
(4) Total Tractor hours X section	995	858	1691
(5) Total Mls per Tractor hour (Army Area)	2.6	2.3	1.2
(6) Total Mls per Tractor hour B section	2.3	2.3	1.2
(7) Total Mls per tractor hour C section	2.9	2.3	1.2
(8) Total Mls per Tractor hour X section	2.9	2.3	1.2
(9) Av. gr. ton mls per tractor per day (A. Area)	413	237	245
(10) Av. gr. ton mls per tractor per day B section	519	325	306
(11) Av. gr. ton mls per tractor per day C section	248	144	157
(12) Av. gr. ton mls per tractor per day X section	401	216	242
(13) Loaded wag. mls per tractor hr. (Army Area)	2.8	2.1	2.2
(14) Loaded wag. mls per tractor hr. B section	3.5	2.3	2.7
(15) Loaded wag. mls per tractor hr. C section	1.4	1.3	1.0
(16) Loaded wag. mls per tractor hr. X section	2.8	2.4	2.3
(17) Av. trac. train loaded (Army Area)	13.6	10.8	11.0
(18) Av. trac. train loaded B section	19.1	11.8	12.0
(19) Av. trac. train loaded C section	11.7	10.0	11.4
(20) Av. trac. train loaded X section	10.3	10.1	10.0
(21) Av. daily no. of tractors under repairs (A Area)	23	20	13
(22) Av. daily no. of tractors under repairs B section	4	3	4
(23) Av. daily no. of tractors under repairs C section	1	0	4
(24) Av. daily no. of tractors under repairs X section	--------	--------	5

Appendix No. 2, Operating Statistics Light Railway III Army (N).

	January-February—Week ending—		
	Jan. 25.	*Feb. 1st.*	*Feb. 7th.*
(25) Av. daily no. of tractors working (A. Area)	23	27	25
(26) Av. daily no. of tractors working B section	9	9	9
(27) Av. daily no. of tractors working C section	5	6	6
(28) Av. daily no. of tractors working X section	9	12	10
(29) Mls per trac. in service per day (A Area)	38	27	27
(30) Mls per trac. in service per day B section	14	33.5	32
(31) Mls per trac. in service per day C section	12	24	20
(32) Mls per trac. in service per day X section	16	24	28
(33) Gals. petrol per ml (Army Area)	52	54	61
(34) Gals. petrol per ml B section	71	61	61
(35) Gals. petrol per ml C section	51	56	73
(36) Gals. petrol per ml X section	39	44	54
(37) Lub. oil in pts. per 100 mls (Army Area)	24	21.8	28
(38) Lub. oil in pts. per 100 mls B section	34	29	27.5
(39) Lub. oil in pts. per 100 mls C section	28	21.1	34.4
(40) Lub. oil in pts. per 100 mls X section	16	13.7	25.4

THE COBLENZ PONTON BRIDGE.[1]

By

Maj. J. W. Skelly,
Corps of Engineers.

On the River Rhine, at Coblenz, and at a number of other places, there is found in public use an improved form of ponton bridge, which, while common in military operations, has in America, when attempted as a more permanent commercial structure, been usually found very difficult to maintain, and therefore short-lived.

Some of these German bridges are very old, the Coblenz bridge having been built in 1819. The situation on the Rhine is peculiarly favorable, the stream being comparatively narrow, with fair but not excessive depths, and stable bottom and banks. Furthermore there is but little interference from running ice, the average annual period of interruption due to this cause being only nineteen days. Drift, which is so common and troublesome on American rivers, is here unknown. The extreme variation in stage at Coblenz is only 8.58 meters (28.1 feet), between 0.62 meter (extreme low) and 9.20 meters (extreme high). This extreme high stage has been reached but twice in the last two hundred fifty years, however, and the ordinary annual fluctuations are scarcely 20 feet. By way of comparison it may be stated that the extreme variation of the Ohio River at Cincinnati is 71 feet, and of the Mississippi, 40 feet at St. Louis and 46 feet at Memphis.

The Coblenz ponton bridge (*schiffbrücke,* or bridge-of-boats) spans the Rhine about 2,300 feet above the mouth of the Moselle River, and connects Coblenz on the left bank at a point about 300 feet above the Rheinstrasse, with Ehrenbreitstein on the right bank, at the foot of Kirchstrasse, being practically a continuation of these streets, which are main thoroughfares. The river at this point is about 1,000 feet wide.

The bridge at ordinary stages is about 1,050 feet long, and is composed of 14 sections—two draw sections, 98 feet and 81 feet in

---

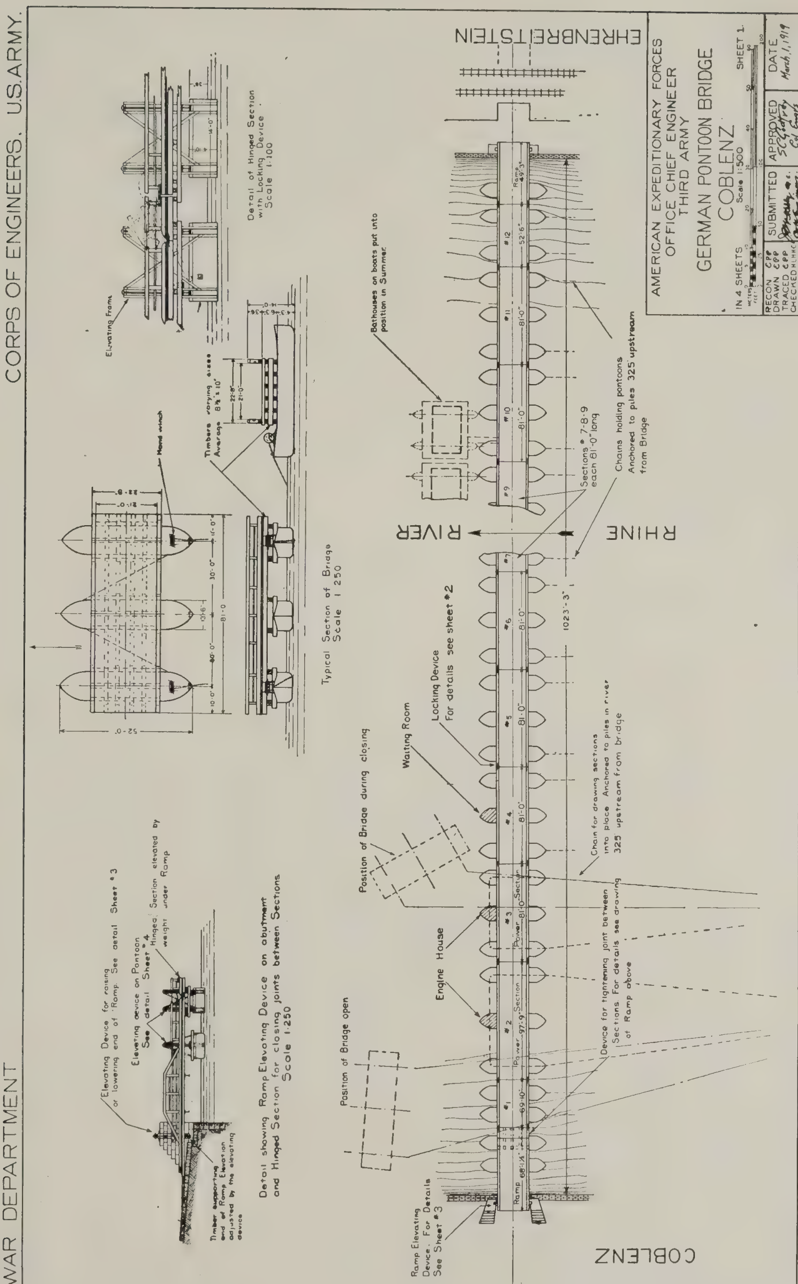
[1]Prepared in the Office of the Chief Engineer, Third Army, March 20, 1919.

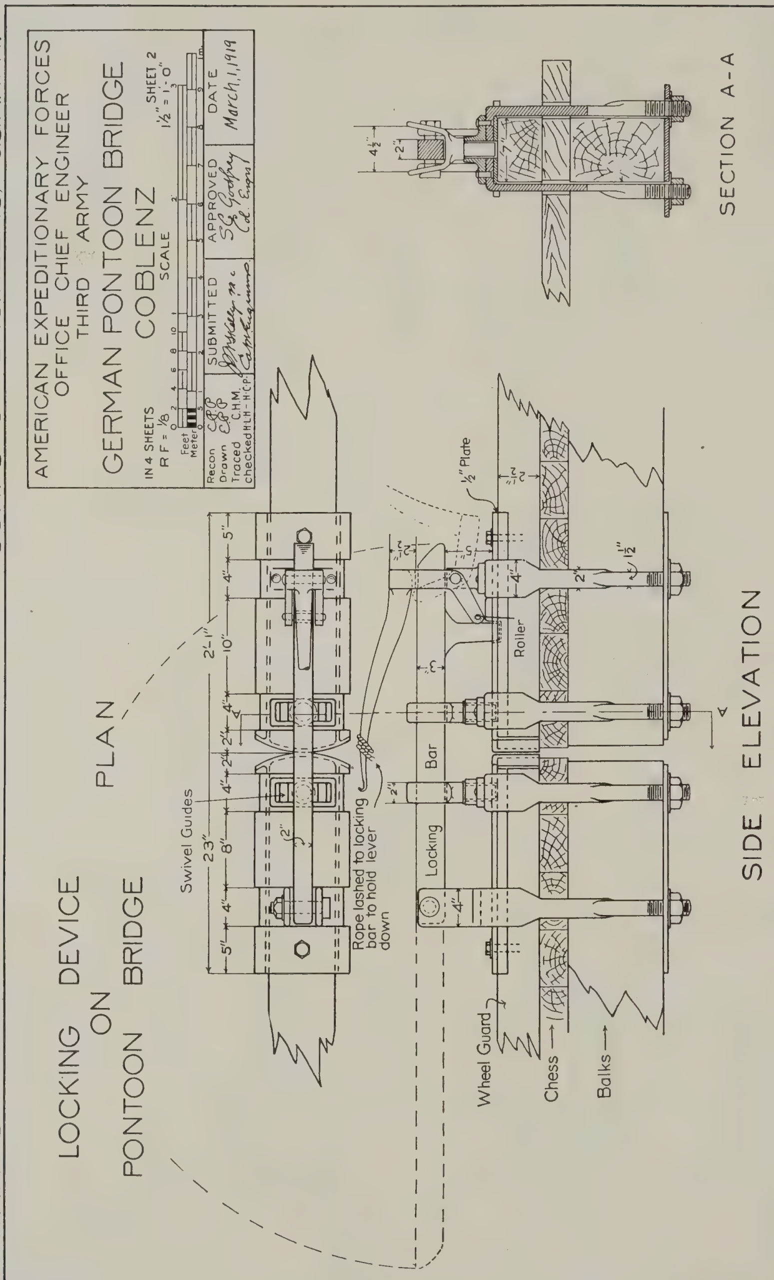
length, equipped with steam winches for quick maneuvering; eight regular fixed sections 81 feet long, and at the ends two short ramp sections about 50 feet long. Other sections are held in reserve for use as required. Ramp sections and the buttresses on shore are provided with raising and lowering devices (Sheets 3 and 4) for adjusting the height of approaches to suit the river stage. In summer bath houses are anchored below the pontons near the right bank.

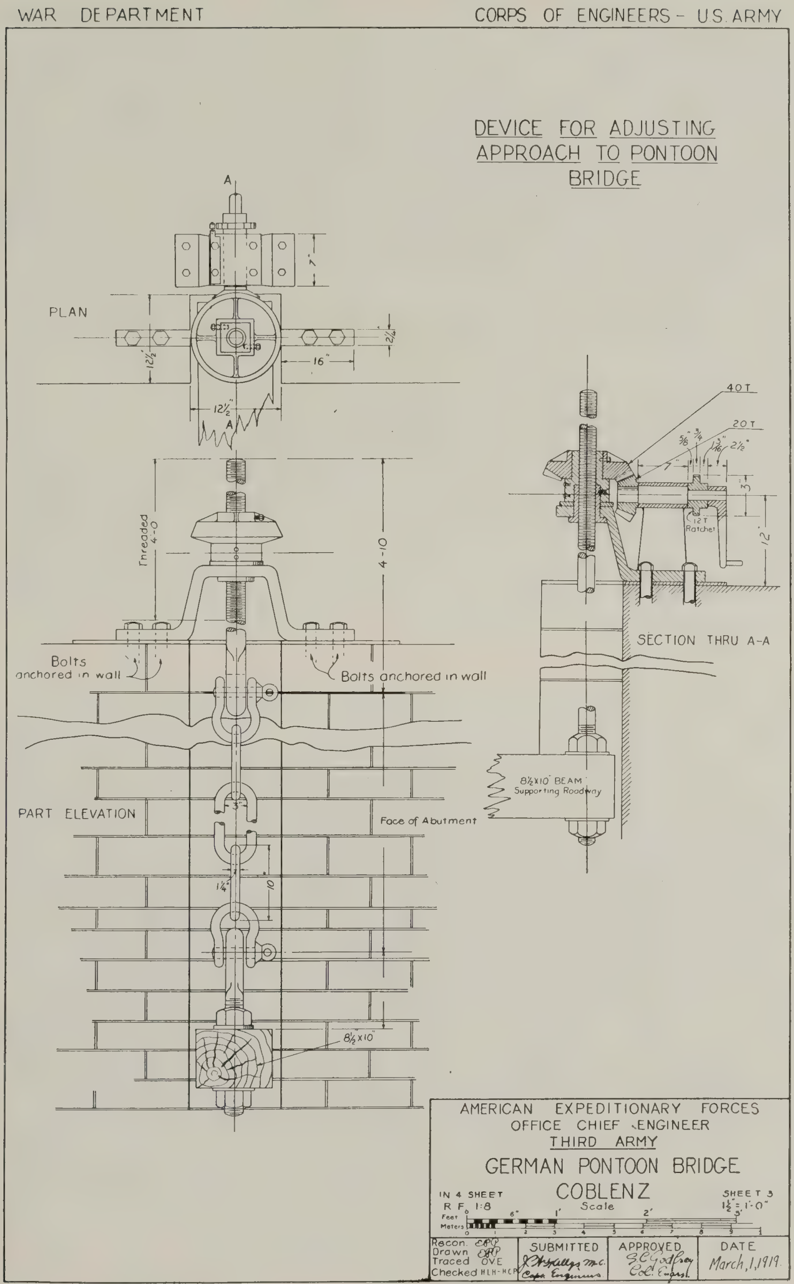
The pontons are of iron and were constructed prior to 1870. Originally they were of wood, and this type is found at other places. They are small double-end or "model" barges, generally 13 feet 6 inches beam by 52 feet length, three pontons being used with each regular section and usually two to each ramp section. The stringers or balks, six in number, average 8½ inches by 10 inches in section, but these as well as the pontons are not uniform in size. The planking consists of two 2-inch layers. The clear width of roadway is 21 feet. Each ponton has in plan, an area of 600 square feet and a net freeboard of about 2 feet, hence the available buoyancy for live load is 37½ tons, though in practice the heaviest load is limited to 15 tons carried on four wheels.

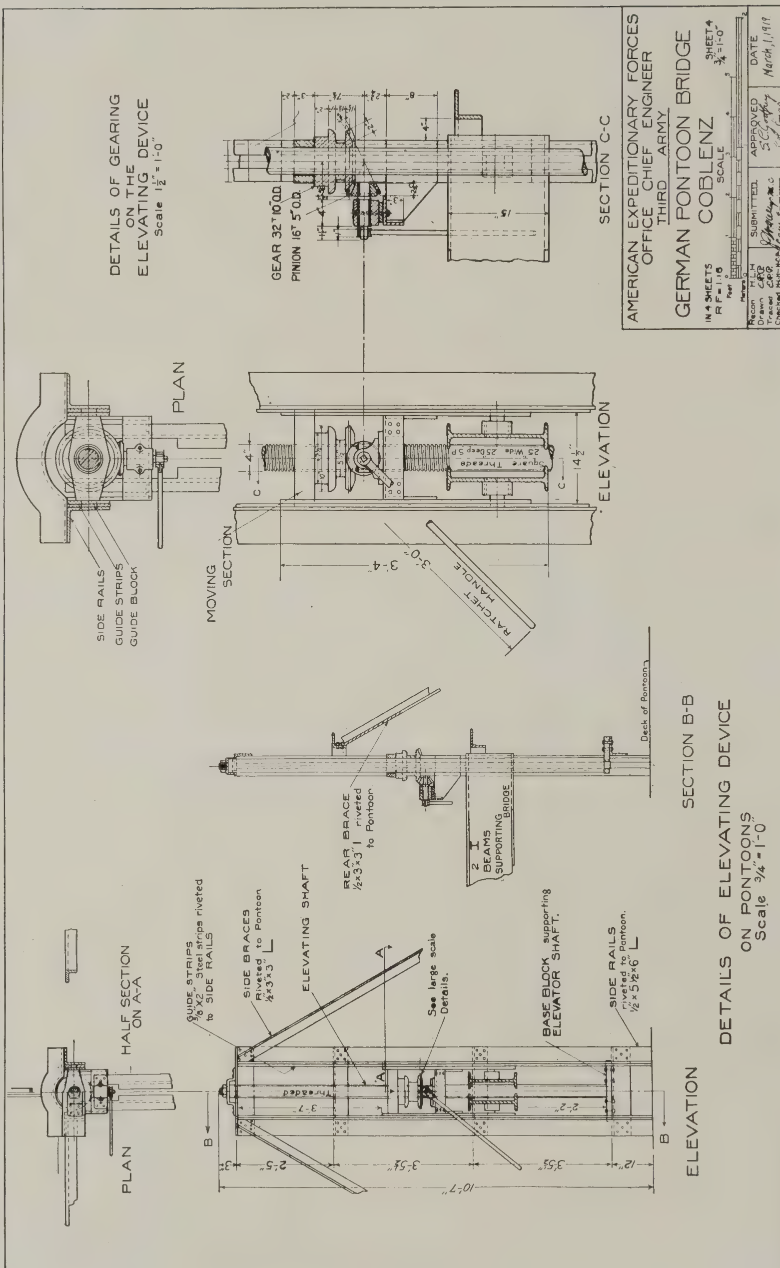
The anchorages are piles driven in the river bed in clumps of threes about 300 feet above the pontons, their tops projecting but a few feet above the bottom. From these clumps chains lead downstream to the pontons, whose position is adjusted by means of hand winches as shown (Sheet 1). There is also a cross chain a short distance below the clumps, which forms a continuous line across the river and furnishes a convenient means of locating the anchorages, as it can be readily picked up and followed throughout its length. Its use, however, is only possible here because of the almost entire absence of sediment; otherwise, as for instance in a silt-bearing river like the Mississippi, it would soon be buried beyond recovery. Fixed sections of three pontons have anchorage chains from the outer pontons only, the middle ponton being fastened to the other two. (Sheet 1.)

The two draw sections are maneuvered quite ingeniously as well as expeditiously. To open the draw, guard rails are first lowered across the roadway, the locking devices (Sheet 2) making the sections fast are next opened and the hinged section (Sheet 1) lifted, the anchor chains on the draw sections are then payed out, allowing these sections to drop back and clear the fixed pontons. The chains on the inner pontons (away from the center of the

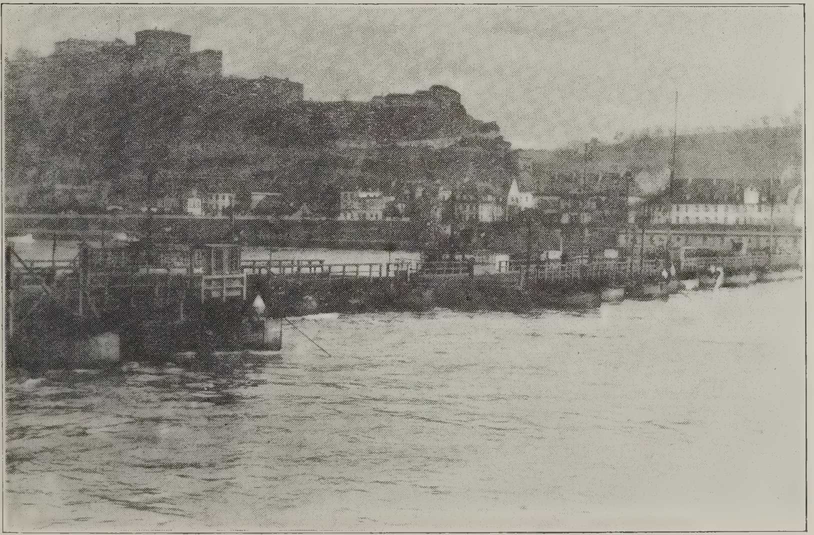

WAR DEPARTMENT
CORPS OF ENGINEERS. U.S.ARMY.
AMERICAN EXPEDITIONARY FORCES
OFFICE CHIEF ENGINEER
THIRD ARMY
GERMAN PONTOON BRIDGE
COBLENZ
Scale 1:500
IN 4 SHEETS
SHEET 1.
RECON
DRAWN
TRACED
CHECKED
SUBMITTED
APPROVED
DATE
March 1, 1919
EHRENBREITSTEIN
COBLENZ
RIVER
RHINE
1023'-3"
Sections # 7-8-9 each 81'-0" long
Chains holding pontoons Anchored to piles 325' upstream from Bridge
Bathouses on boats put into position in Summer.
Locking Device For details see sheet # 2
Waiting Room
Position of Bridge during closing
Engine House
Position of Bridge open
Ramp Elevating Device. For Details See Sheet # 3
Chain for drawing sections into place Anchored to piles in river 325 upstream from bridge
Device for tightening joint between Sections. For details see drawing of Ramp above
Detail of Hinged Section with Locking Device. Scale 1:100
Elevating Frame
Typical Section of Bridge Scale 1 250
Timbers varying sizes Average 8 1/2" x 10"
Hand winch
Elevating Device for raising or lowering end of Ramp. See detail Sheet # 3
Elevating device on Pontoon See detail Sheet # 4
Hinged Section elevated by weight under Ramp
Timber supporting end of Ramp Elevation adjusted by the elevating device
Detail showing Ramp Elevating Device on abutment and Hinged Section for closing joints between Sections
Scale 1:250


WAR DEPARTMENT
CORPS OF ENGINEERS, U.S.ARMY.
AMERICAN EXPEDITIONARY FORCES
OFFICE CHIEF ENGINEER
THIRD ARMY
GERMAN PONTOON BRIDGE
COBLENZ
IN 4 SHEETS
SHEET 2
R F = 1/8
1½" = 1'-0"
SCALE
Feet
Meters
Recon
Drawn
Traced C.H.M.
checked
SUBMITTED
APPROVED
DATE
March, 1, 1919
LOCKING DEVICE
ON
PONTOON BRIDGE
PLAN
Swivel Guides
Rope lashed to locking bar to hold lever down
½" Plate
Roller
Locking
Bar
Wheel Guard
Chess
Balks
SIDE ELEVATION
SECTION A-A


WAR DEPARTMENT
CORPS OF ENGINEERS - U.S. ARMY
DEVICE FOR ADJUSTING APPROACH TO PONTOON BRIDGE
PLAN
PART ELEVATION
SECTION THRU A-A
Threaded 4-0
4-10
Bolts anchored in wall
Bolts anchored in wall
Face of Abutment
8½x10
8½x10 BEAM Supporting Roadway
40 T
20 T
12 T Ratchet
AMERICAN EXPEDITIONARY FORCES
OFFICE CHIEF ENGINEER
THIRD ARMY
GERMAN PONTOON BRIDGE
COBLENZ
IN 4 SHEET
SHEET 3
R.F. 1:8
1½" = 1'-0"
Scale
Feet
Meters
Recon.
Drawn
Traced
Checked
SUBMITTED
APPROVED
DATE
March, 1, 1919


WAR DEPARTMENT
CORPS OF ENGINEERS, U.S. ARMY.
AMERICAN EXPEDITIONARY FORCES
OFFICE CHIEF ENGINEER
THIRD ARMY
GERMAN PONTOON BRIDGE
COBLENZ
IN 4 SHEETS
SHEET 4
DETAILS OF GEARING
ON THE
ELEVATING DEVICE
DETAILS OF ELEVATING DEVICE
ON PONTOONS
PLAN
HALF SECTION ON A-A
ELEVATION
SECTION B-B
SECTION C-C
MOVING SECTION
RATCHET HANDLE
SIDE RAILS
GUIDE STRIPS
GUIDE BLOCK
SIDE BRACES
ELEVATING SHAFT
REAR BRACE
BASE BLOCK supporting ELEVATOR SHAFT.
See large scale Details.
2 BEAMS SUPPORTING BRIDGE
Deck of Pontoon
GEAR 32T 10" O.D.
PINION 16T 5" O.D.
Square Threads
SUBMITTED
APPROVED
DATE
March, 1, 1919

View looking downstream; Fortress Ehrenbreitstein in right background.



View from Coblenz (left bank); draw span partly open; Fortress Ehrenbreitstein in left background.

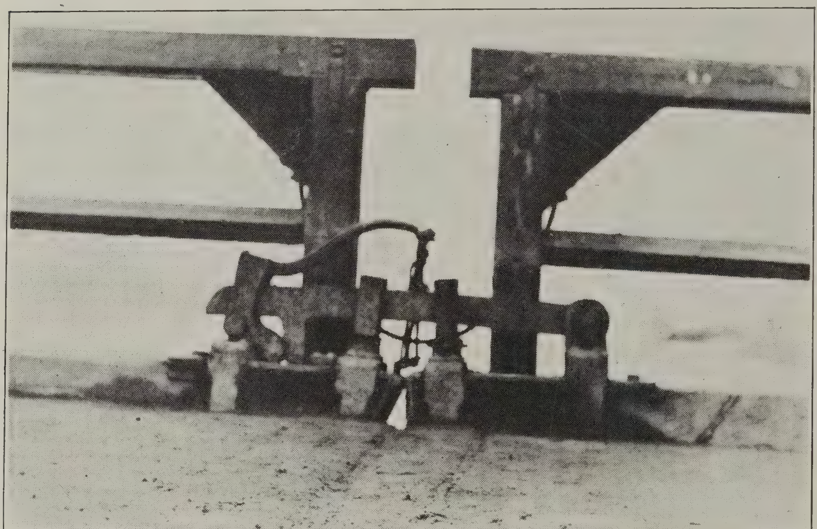
View from Ehrenbreitstein (right bank); frames for adjusting height of roadway to river stage at left.

View from Coblenz; first span raised for high river stage.

View from Coblenz; extension during high river stage.

View upstream side, showing frames for adjusting height of roadway to river stage.

opening) are payed out more rapidly, which causes the sections to take a skewed position, and acting as rudders they are separated by the current, thus quickly clearing the opening. In closing, this action is reversed, the inner pontons being hauled up and the outer slacked off, bringing the sections together, when they are hauled into position, the hinged section and locking devices closed, and the bridge is ready for traffic. Recent observations show the average time required for opening or closing the draw to be 2 minutes 20 seconds. The actual time required for maneuvering

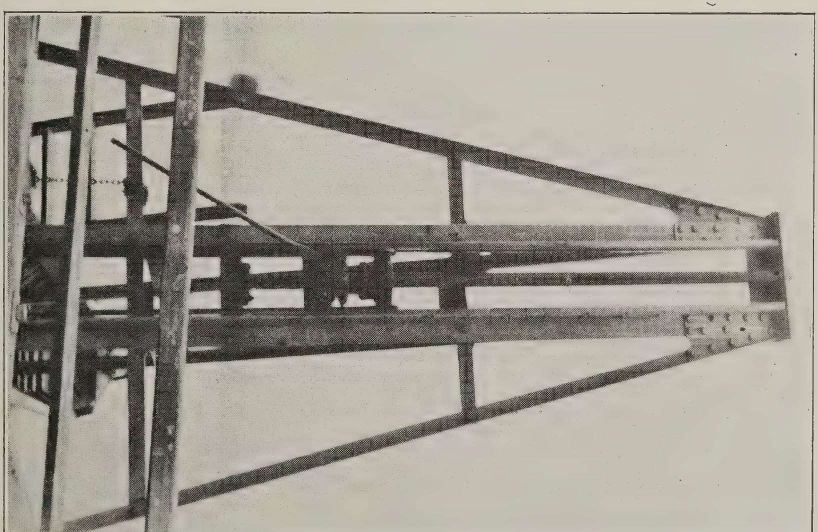


Locking device, holding sections in position.

the pontons averaged 1 minute 20 seconds downstream and 2 minutes 5 seconds upstream. The periods of interruption to bridge traffic varied according to the nature of the vessels passing, and their direction, from 5 minutes to 21 minutes.

The Coblenz bridge is the property of the Prussian State, represented by the Rhine Construction Administration (*Rheinstrombauverwaltung*) by which it is maintained, but for operation it is leased to a private concern, which furnishes the personnel, collects tolls, etc. The cost to the State for maintenance during the twenty years, 1896 to 1915, inclusive, was 781,943.59 marks, the average daily cost being therefore 107 marks. The cost of construction is

Ehrenbreitstein; high water marks.



Near view, frame for adjusting height of roadway to river stage.

unknown, but even at the present time would be much less than for any other type of bridge of equal capacity. Operation and maintenance charges compare favorably with even a fixed bridge, while in convenience of access there is obviated the necessity for the long and otherwise objectionable approaches of a fixed bridge, and it is in fact preferable in this respect to a draw bridge, of which there are none on the Prussian Rhine.

Ponton bridges were formerly maintained below Coblenz at Cologne, Düsseldorf, Wesel and Mülheim, but except at Mülheim, have been replaced with highway bridges of the fixed type; others are reported in operation at thirteen localities on the Rhine above Mannheim, and on two of these railroad traffic is also carried. With the remarkable growth of Rhine navigation between Mannheim and the sea, however, which in 1913 reached the magnificent total of 109 million tons, ponton bridges are becoming a more serious obstruction in this respect, and in consequence are being gradually replaced by high fixed bridges.

THE MILITARY MAPPING PROBLEM IN THE UNITED STATES.

By

Lt. Col. R. C. Kuldell,
Corps of Engineers.

All reports from the American Expeditionary Forces agree to the adequacy and accuracy of the maps of France and especially of the Western Front. Our Infantry and Artillery have been trained in the use of these maps. All movements are ordered and made with utmost confidence that accurate maps exist and are available. The wonderful results accomplished, especially by the Intelligence Service and the Artillery, are due directly to the existence of these maps. Reliance upon these maps has become instinctive throughout all ranks. No such condition exists in the United States. A study of the accompanying chart will show the alarming situation as regards map-preparedness. (Chart I.)

The French maps are of various scales, projections and quadrillage. The sizes of the sheets differ and there is considerable overlapping. Some of these facts are advantageous, others are a distinct disadvantage.

Let us consider these points in order.

THE SCALE.

The most commonly known are the following:

1: 200,000 or 1 cm.=2 kilometers or .317 inch=1 mile;
1: 80,000 or 1 cm.=800 meters or .8 inch=1 mile;
1: 50,000 or 1 cm.=500 meters or 1.27 inches=1 mile;
1: 20,000 or 1 cm.=200 meters or 3.17 inches=1 mile;
1: 10,000 or 1 cm.=100 meters or 6.34 inches=1 mile;
1: 5,000 or 1 cm.= 50 meters or 12.67 inches=1 mile.

Whereas the scales used in the United States are:

1: 250,000 1: 125,000 1: 62,500	Used by the U. S. Geological Survey and the Progressive Military Map of the United States.

1: 21,120 or 3 inches=1 mile;
1: 5,280 or 12 inches=1 mile.

It will be seen that there is a certain similarity between the two systems, especially the last three figures in each column. The French system, of course, is metric and is consistent throughout, with the possible exception of the 1: 80,000 scale. The American system as used by the U. S. Geological Survey and the Progressive Military Map, begins with 1: 1,000,000 and doubles this each time to 1: 500,000; 1: 250,000; 1: 125,000 and 1: 62,500. We thus arrive at the scale most often met with in the maps of this country.

Most of the maps of this scale are made by the Topographic Branch of the U. S. Geological Survey and all who have used these maps will agree that for a map of that scale, they are the equal of any map in the world. The scale, however, is very unfortunate. In this country where distance is thought of in terms of inches, feet, yards and miles, ninety-nine persons out of a hundred in using this map use it as a one-inch to the mile map (1: 63,360). Thus a map which has been made accurately at large expenditure of time and money in reality gives distances only approximately.

As to the 12-inch, 6-inch and 3-inch scales, their value depends entirely on the following all-important question. Shall we hereafter use throughout our service the decimal scales both as to distances and contour intervals, or shall we adhere to the standard units of measure of our country? This question can not be answered here but a few considerations will be given.

As to the value of the two systems in the abstract, there can be no argument. The metric system is superior in every respect and why our country wisely discarded the English monetary system for the decimal but retained the English units of measure, is a mystery. The fact remains, however, that all our men have grown up with our present system. A number of inches, yards or miles instantly calls to mind a definite ground distance, whereas a number of meters or kilometers means a mental calculation to convert it to yards or miles with a feeling that the result is only approximate.

To obtain funds to make the desired maps, we must prove that these maps are of commercial value. The popularity of the Geological Survey Atlas Sheets is well known. The public knows that these maps are well worth their cost. Were we to print our maps on the scale of 1: 20,000, with contour interval of 5 meters, it would be like publishing a newspaper in a foreign language, and about as popular.

On the other hand, our new Artillery is supplied with instruments on the metric scale, our officers have learned to use this scale


STATUS
OF
PROGRESSIVE MILITARY MAP
OF THE
UNITED STATES
Notes
Sheets are on either a scale of 1:62,500 or 1:125,000 depending on the importance of the area mapped
Each sheet on scale of 1:125,000 will include within the border lines one degree of longitude and one half degree of latitude
Each sheet on scale of 1:62,500 will include within the border lines 30' of longitude and 15' of latitude
132 N
PORTO RICO
HAWAIIAN ISLANDS
MAINE
VER.
MASS.
CONN.
NEW YORK
PENN.
N.J.
MD.
WEST VIRGINIA
VIRGINIA
NORTH CAROLINA
SOUTH CAROLINA
GEORGIA
FLORIDA
ALABAMA
MISSISSIPPI
LOUISIANA
TENNESSEE
KENTUCKY
OHIO
INDIANA
ILLINOIS
MICHIGAN
WISCONSIN
MINNESOTA
IOWA
MISSOURI
ARKANSAS
TEXAS
OKLAHOMA
KANSAS
NEBRASKA
SOUTH DAKOTA
NORTH DAKOTA
MONTANA
WYOMING
COLORADO
NEW MEXICO
ARIZONA
UTAH
NEVADA
IDAHO
WASHINGTON
OREGON
CALIFORNIA

and prominent Artillerymen declare they will never go back to the old units.

These are the main considerations that must govern in answering the above question. Either system may be used in the preparation and reproduction of the map, the metric unit being perhaps the simpler for the engineer. Whichever way the question is answered the decision should be made at once. This is of prime importance; no progress can be made until this question is settled.

A suggested system of scales for both systems follows:

Metric.	Purpose.		English.
1: 200,000	........Aeronautic Maps........	1: 190080	1/3 inch =1 mile.
1: 50,000	.Staff and Progressive Mil. Maps.	1: 63360	1 inch =1 mile.
1: 20,000	.....General Maneuver Map.....	1: 21120	3 inches=1 mile.
1: 10,000	.........Artillery Map.........	1: 10560	6 inches=1 mile.
1: 5,000	..Local Defense or Attack Map..	1: 5280	12 inches=1 mile.

Of these only the 1:50,000 and the 1:10,000 maps should be made in the field and where the 1:10,000 map is made the 1:50,000 map need not be made. All other maps are made by reduction except the 1:5,000 map, which is made in skeleton only from the 1:10,000 field sheets and filled in as needed by additional field work.

In general, therefore, the task of securing adequate and accurate maps of the United States and its possessions consists in mapping at the scale of 1:50,000 this entire area, except those areas of strategic importance and training areas which should be mapped at 1:10,000.

A considerable area has been mapped by the U. S. Geological Survey and maps on scale of 1:62,500 published. The field work on these maps was done on a scale of 1:48,000 and it would therefore be possible to reproduce these field sheets on the scale of 1:50,000. To change the contour interval from feet to meters would require a great deal of costly work, but it could be done. On the other hand, if the English units are retained, the 1:63,360 scale should by all means replace the 1:62,500 scale, which is neither metric nor English.

The 1:10,000 scale for the field work should be used rather than the 1:20,000. The areas which are to be covered by the large scale maps are relatively small. They consist of the territory within a

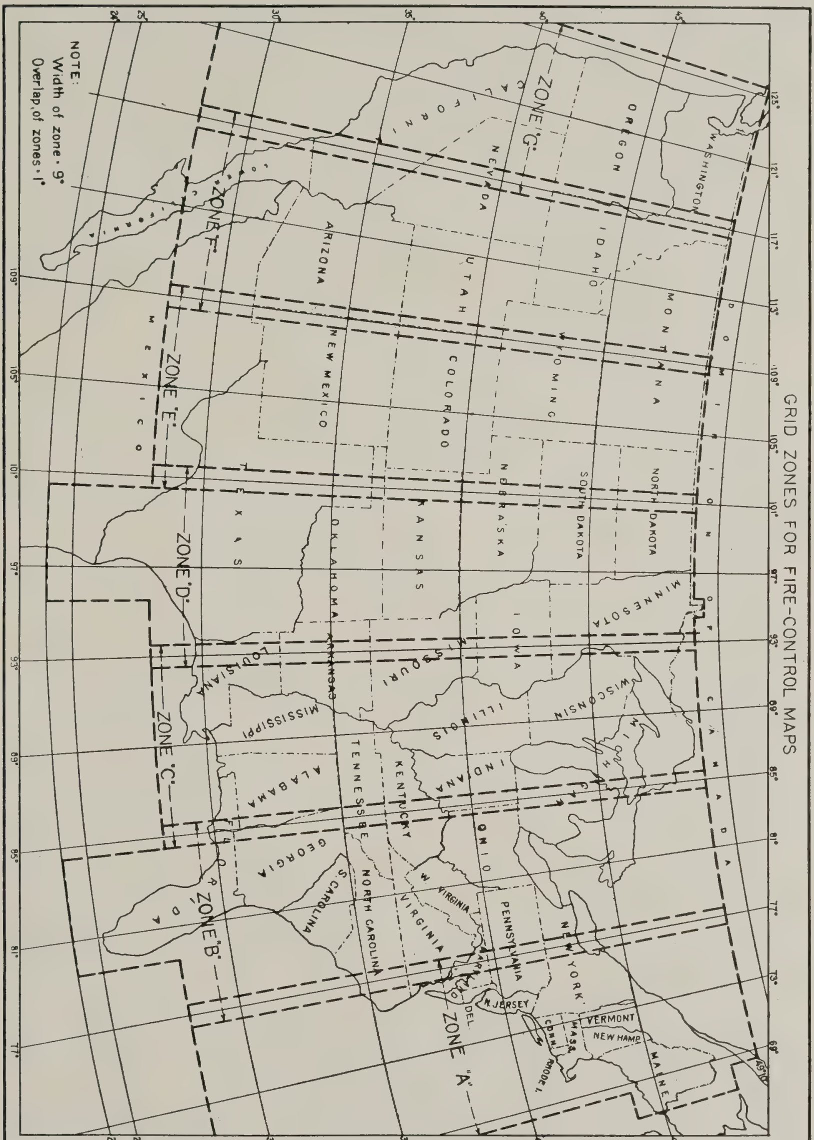

GRID ZONES FOR FIRE-CONTROL MAPS
NOTE:
Width of zone - 9°
Overlap of zones - 1°
ZONE "A"
ZONE "B"
ZONE "C"
ZONE "D"
ZONE "E"
ZONE "F"
ZONE "G"
D O M I N I O N O F C A N A D A
M E X I C O
WASHINGTON
OREGON
CALIFORNIA
NEVADA
IDAHO
MONTANA
UTAH
ARIZONA
WYOMING
COLORADO
NEW MEXICO
NORTH DAKOTA
SOUTH DAKOTA
NEBRASKA
KANSAS
OKLAHOMA
TEXAS
MINNESOTA
IOWA
MISSOURI
ARKANSAS
LOUISIANA
WISCONSIN
ILLINOIS
MISSISSIPPI
MICH
INDIANA
KENTUCKY
TENNESSEE
ALABAMA
GEORGIA
FLORIDA
OHIO
W. VIRGINIA
VIRGINIA
NORTH CAROLINA
S. CAROLINA
PENNSYLVANIA
NEW YORK
N. JERSEY
DEL.
MARYLAND
VERMONT
NEW HAMP.
MASS.
CONN.
RHODE I.
MAINE

Chart II.

radius of 20 miles of all important seacoast and border cities and the interior training areas. In all cases, the 1:10,000 map will be demanded by the Artillery and in many parts of the area the smaller Infantry units will demand the 1:5,000 map. To produce these satisfactorily, the field scale should not be less than 1:10,000.

Closely allied with the question of scale is that of contour interval. Unlike the scale, the contour interval can not be changed by photographic enlargement or reduction. This is a serious objection to prescribing rigidly the contour interval for each scale. Another and more important objection to this practice is the freedom of expression that is taken from the topographer when he is required to portray level ground and mountainous ground on the same scale with the same contour interval. A rule that has been adopted by the Chief of Engineers is as follows:

The contour interval will be determined by the Chief of Engineers, having in view the maximum detailed delineation of the ground forms consistent with cartographic clearness. For each area the Chief of Engineers approves the contour interval before field work is begun.

THE PROJECTION AND GRID.

The French use principally the Bonne and the Lambert projections. An attempt to follow their example and use the Lambert projection for the United States proved a costly failure. The U. S. Geological Survey and the Corps of Engineers have adopted the Polyconic projection.

The necessity for any projection, of course, lies in the fact that the earth's surface is spherical and the paper on which the map is printed is a plane. The problem, therefore, lies in representing as accurately as possible (absolute accuracy being theoretically impossible) the spherical surface of the earth on the plane surface of the paper. With the introduction of the grid on military maps, this problem became complicated.

The method used by the U. S. Geological Survey consists in making a separate polyconic projection for each 15 minute by 15 minute sheet based on its central meridian. The distortion is entirely negligible. However, were all these sheets to be placed edge to edge they would form a sphere similar to a ball of hammered metal. No spherical surfaces exist, but a nearly perfect sphere made of a vast number of plane surfaces results. A large number

of these sheets can not be placed edge-to-edge on a large table without showing Vs between edges.

The map grid from its very character must be a plane. All lines are right lines and either parallel or perpendicular to all other lines. To superimpose a continuous grid on a series of map sheets requires that all sheets for the area be on a single plane that is on a single projection. We therefore have two contending requirements that are diametrically opposite. The grid must be a plane throughout its continuance, the projection can not be a plane without causing distortion and inaccuracy. The greater the area represented on a single plane, the greater the distortion and error of representation. It is necessary to seek a compromise for the best solution.

The area of France is relatively very small when compared to that of the United States. It is possible, with permissible distortion, to represent all of France and Belgium on a single cone, such as the Lambert Projection, and superimpose on it a universal grid. In attempting to place continental United States on a single plane the distortion of maps of scales larger than 1:50,000 was beyond allowable limits so that in the worst areas a factor would have to be printed on each map and distances scaled from the maps multiplied by this factor to get true distances. The plan had to be abandoned.

The most practicable plan, therefore, consists of using the Polyconic projection and determining upon a per cent of distortion beyond which it shall not be permissible to go. There is no distortion along the meridian on which the projection is based. The distortion gets worse east and west from this meridian until it reaches the allowable limit. This may be taken as 4½ degrees of longitude. The width of the projection will, therefore, be 9 degrees of longitude. A zone 9 degrees in longitude and extending north and south across the entire United States can be placed on a single plane and a continuous grid superimposed on the maps of this area. The north and south lines of this grid are parallel to the central meridian and the east and west lines are, of course, perpendicular to it. The entire area of the United States is covered by seven such zones overlapping one degree. In the area of overlap the north and south lines of one grid system make an angle with the north and south lines of the other equal to the angle of convergence of the two central meridians. This can not be avoided. When the grid first came into use in this country, it was simply drawn in a hap-

hazard way on the sheet without any attempt to tie it to the features of the map.

It is just as important that the features shown on the map be tied to the grid as it is that they be tied to the projection. In other words, we now use rectangular coordinates instead of spherical (latitude and longitude) and these rectangular coordinates for control points must be computed from the field notes of the surveyor and not simply scaled from the map. To make this possible, tables have been computed for the grid above described (one system of 9 degrees longitude applies to every other system) giving the rectangular coordinates of the intersection of every 5 minutes of latitude with every 5 minutes of longitude in the area. (Chart II.) With this table and a simple formula it is possible to furnish with each map sheet a list of control points with their computed spherical (latitude and longitude) and rectangular (grid) coordinates, This is particularly necessary for Artillery work.

THE SIZE OF SHEET.

For the 1:50,000 or 1:63,360 maps, the standard already adopted by the Chief of Engineers is the 15 minute by 15 minute sheet, the border lines being the bounding meridians and parallels. The grid has no place on a map of this scale. The lines of the grid would be so close that they would greatly add to the difficulty of showing with clearness the amount of detail desired. This type of map is used chiefly for staff study and road marches.

For the Battle Maps the following sizes have been adopted by the Chief of Engineers.

Metric—

1:20,000—20 kilometers east and west;
12 kilometers north and south;
1:10,000—10 kilometers east and west;
6 kilometers north and south;
1: 5,000— 5 kilometers east and west;
3 kilometers north and south;

English—

1:21,120—20,000 yards east and west;
12,000 yards north and south;
1:10,560—10,000 yards east and west;
6,000 yards north and south;
1: 5,280— 5,000 yards east and west;
3,000 yards north and south.

For either system, the size of sheet is the same throughout; the area covered being proportional to the scale. It prints with adequate margin on commercial size paper. It is not too large to be easily handled, yet covers considerable area. The grid lines form the border of the sheet. The north and south bounding grid lines must be multiples of 12,000, 6,000 or 3,000, and the east and west bounding lines must be multiples of 20,000, 10,000 or 5,000, depending on the scale. This absolutely prevents overlapping; every sheet has its definite place in the grid system.

WAYS AND MEANS.

The accompanying chart shows the present map situation, the above discussion explains the ultimate object. The desirability and necessity of accomplishing this object needs but little emphasis.

As a military necessity, military preparedness is generally thought of in terms of men and matériel. This war has demonstrated that maps are as essential to an army as ammunition. It has also demonstrated that men and matériel can be obtained in from six months to a year. How much of our eastern coast could we map in a year with invasion threatening? Maps must be made deliberately in time of peace. For any given area it is safe to assume that it will take one year from the time the survey is begun until the finished sheet is available.

Our officers have learned to use and depend upon accurate maps. They are now returning to train troops in this country. As training areas are established, the first call will be for maps, not sketches, but real maps. We must be ready to undertake this work with a definite plan of action, as soon as the areas are designated.

Not only the strategic and training areas must be mapped, although these must come first, but the entire interior must be covered. Though these areas may be used for maneuvers and cross-country flying, the chief value of these maps will be civil. It is anticipated that with the demobilization of the Army will come a great move to develop our waste and unused lands. It will save vast sums of money if this development could be planned on accurate maps.

The following agencies are engaged on map work and maintain personnel and equipment for this purpose. Each has its particular purpose; many go over the same area, as the maps of the preceding agency do not meet the needs of all.

FEDERAL:
- *War Department—*
  - General Staff (Foreign);
  - Corps of Engineers—
    - River and Harbor;
    - Lake Survey;
    - Military Mapping;
  - Quartermaster Corps (Forts and Reservations).
- *Navy Department—*
  - Hydrographic Branch.
- *Commerce Department—*
  - U. S. Coast & Geodetic Survey.
- *Interior Department—*
  - U. S. Geological Survey—
    - Geological Branch;
    - Topographical Branch;
  - Land Office;
  - Indian Bureau (Indian Reservations);
  - Forest Service (National Forests);
  - Reclamation Surveys.
- *Agriculture—*
  - Department of Roads and Rural Engineering;
  - Soil Survey.
- *Post Office—*
  - Postal Route Maps.
- *International Boundary Commission—*
  - Two Canadian;
  - Two Mexican.

STATE:
- Each state maintains similar organizations on a smaller scale.

COUNTY:
- County Engineers (highway);
- County Surveyors.

CITY:
- City Engineers.

CIVIL:
- Railroads;
- Irrigation Projects;
- Real Estate Developments.

There are no doubt many other agencies at work on maps, but these have come to the writer's attention and are sufficient to indicate the duplication and lack of coördination.

The first step taken by the Chief of Engineers, when he established an officer in charge of military mapping in his office, was to establish close liaison with all the agencies. As a result, it became known exactly what had been done and what maps were available.

Great quantities of topographical data were gathered and filed. A standard form of map sheet, 15 minutes by 15 minutes, scale 1/62,500, was adopted and a sheet prepared for each quadrangle in the United States. All existing data of primary or "control" value was accurately plotted and traced on these sheets. By compiling and adding all other topographic data there resulted an "Advance Sheet," which is known to be the best existing map of the area and it is standardized.

To make final maps of these areas only the very best methods, personnel and equipment should be used. It is a sad fallacy to use sketching-case methods and hope to get maps of permanent value. A map is a great deal like a building. To build lightly and hastily means no satisfaction during the life of the building; the assurance that it will some day be necessary to rebuild; and the possibility that the building may fail in a crisis. Why not build solidly and securely at first? The only excuse for not doing so is pressing military necessity. Build a good foundation. The U. S. Coast & Geodetic Survey has with rare foresight cut this country up into large figures. Where the Coast & Geodetic Survey triangulation areas moved across the country in long steps anxious only to reach the border, we must cut in many more points so that the topographer will never have to go far to find "bed rock" on which to begin his foundation. For each sheet there must be sufficient instrumental control of an accuracy equal to 1 in 5,000. These control lines must make a net over the entire country and be tied to the primary control of the Coast Survey.

Upon this net the building proper should be built. Years of experience in all kinds of country with good men and bad have developed in the U. S. Geological Survey a method known as the plane-table method, which it is believed far surpasses the transit and stadia method both in speed and accuracy. A map constructed by trained personnel with these methods can be completed in nearly the same time as one made by untrained personnel using the sketching case and the results would be final and dependable.

During the war the Chief of Engineers organized a unit known as the 472nd Engineers. Its members were selected for their experience and education to be map men. A training school was established with trained U. S. Geological Survey topographers as instructors. Other students were sent to drafting and lithographing schools. Still others were sent as student assistants to officers actually engaged in field work. In this way, the Chief of Engi-

neers soon had available trained personnel which could be thrown into any emergency task that might arise.

A similar organization must be maintained in time of peace. Map work is highly technical and highly important. A trained man can turn out reliable work with greatest economy of time and money, the untrained man will waste time and money and while his results may bear office inspection they will, in general, be far from accurate.

Good map work can not be done by details from sapper regiments. Men and officers dislike the work. It takes them from their camp or garrison into the woods, where they must work long and hard with no change and no amusement. The first part of their work will be useless and by the time they are capable of doing good work the field season will be over and the next season a new detail will be sent out.

An organization made up of officers and men with special ability and training in this work can be depended upon to do reliable work in the shortest time.

The large scale work must be handled in a very similar way. It requires a great deal more attention on the control work. The topography is therefore relatively simple.

In order to handle the situation after the war with credit, the Corps of Engineers will require:

Funds;
Trained personnel;
Equipment, including transportation.

The funds, of course, must be obtained from Congress. The amount that will be obtained will be much larger if the Engineers can demonstrate past success and produce a definite logical plan of action with an organization capable of carrying it out.

Trained personnel will never be available under the old system. The sapper regiments do not train for this kind of work. In the plans for the reorganization of the Army, the Corps of Engineers must insist upon, at least, one regiment of "Engineers Surveying and Mapping." Many of the officers and high non-commissioned officers can be obtained from existing mapping agencies, the remainder must be trained in school or in the field. Military organization is especially adapted to mapping purposes. It insures constant and efficient field inspection; it permits the promotion of competent men to positions of higher responsibility instead of simply increasing their pay and holding them to the same work.

EQUIPMENT.

With the return of our troops there will be available ample surveying equipment. This should be centralized and careful records kept of its whereabouts in order that it may be kept in constant repair and available for instant use. As map work covers large areas and requires rapid transportation, every effort should be made to hold a large number of the Dodge light wagons and touring cars for map work. The use of motor transportation facilitates field inspection, field supply, rapid moves of field parties upon completion of assigned area, and rapid field work within the party. It adds to the conveniences and lightens the unpleasant arduous work of field surveying.

Military Mapping is one of the past war obligations of the Corps of Engineers. It presents a fine field of usefulness to the Army and the Country. If taken at once, we will be ready when the call comes, if delayed, opportunities to obtain the essentials for the work will pass and as soon as troops begin to train there will be a cry for maneuver maps. If we cannot supply that demand, we will have failed in our duty and we will lose a branch of engineer work that is open to us in peace as well as war.

Comment on the Military Mapping Problem in the United States.

By

Col. E. H. Marks,[1]
Engineers.

The above article very ably points out the many facts to be considered in the adoption of the mapping policy for the Army of the United States.

The adoption of the metric system by the Army should only follow the adoption of this system by the entire country. This may be done only after the most careful consideration, for it would be no easy task to change the voluminous Government records based upon the English system of measurement. A recent order of the War Department, Bulletin 64, 1918, prescribes scales of maps to be used by the Army as 1 : 10,000 ; 1 : 20,000 ; 1 : 62,500 ; and 1 : 200,000.

---

[1]In charge of Military Survey and Mapping in the Office of the Chief of Engineers, U. S. Army.

By consulting this order, it will be noticed that no definite contour interval is fixed for maps of various scales, but that it is some multiple of 5 feet, or 10 feet, "having in view the maximum detailed delineation of the ground consistent with cartographic clearness."

As the writer points out, this provides for some freedom of the topographic expression, although it gets away from the idea of "the unit system of scales and contour intervals," which, although facilitating the reading of maps, leaves but little room for interpreting topography in various kinds of country.

Confusion has sometimes arisen between the two questions: one, the adoption of the decimal scale for maps; and the other, the adoption of the metric system for measurements, but these two questions are entirely independent of each other. Maps drawn on scales of inches to the mile can be used only with very special scales, which cannot be ordinarily obtained, whereas a map drawn to the decimal scale lends itself to uses with any measuring scale, simply by multiplication. On a map drawn to the decimal scale, it is immaterial what system of units are used, since measurement in any system of units may be performed by means of scales in the same system of units, and at the present time commercial scales dividing feet into hundredths, and yards or meters into thousandths, may be obtained in any store or manufactory dealing with ordinary drawing instruments.

In measuring map distances for military purposes, various results are desired—for marching, road distances in miles; for artillery fire, distances in yards or meters; for tracing trenches, distances in feet. To determine these distances, the graphical scale may be used; distances may be estimated by the eye; a map measurer, or auxiliary scale used. If the graphical scale be used the R. F. is of little concern.

When distances in miles are required, the fact that the 1:10,000 and 1:20,000 scales are within about 5 per cent of the 6 inches = 1 mile, and 3 inches=1 mile scales, respectively, enables one to make close estimates, and with a map measurer or auxiliary scale, distances may be quickly determined by simple arithmetic. By far the most necessarily accurate uses to which a map may be put are, as an aid to trench construction, and in determination of ranges for artillery or machine gun fire: the map then should be constructed to most closely fill these wants, which is by adoption of a decimal scale, so that true distances may be quickly and ac-

curately determined from map distances by use of an auxiliary scale and simple multiplication. To sum up, the use of a decimal scale for maps lends itself generally to measurement in any system of units, but this is not true of any scale which is based upon the relation between inches and miles.

The adoption of the 62,500 scale is indeed unfortunate, but as the majority of topographic maps of this country exist to this scale, the benefit resulting from a change would possibly not be consistent with the large expenditure of funds to reproduce the existing maps to a scale of 1:40,000 or 1: 50,000.

In general, the work of the Corps of Engineers will be confined to the execution of original surveys in our insular possessions, and in the vicinity of the military posts of the United States; and, in the revision of existing topographical maps, particularly those of the Geological Survey; but such work as is done should be made with a view to making it available for civil uses.

The use of sapper troops upon map work, except in emergency, is to be deplored, and our new army should most certainly comprise a topographic unit. Sapper troops are not properly trained for such work, and it seriously interferes with their other training. To depend upon sapper troops to do this work to the necessary exclusion of combat training, can be summed up in the words of the Book of Common Prayer—"We have done those things which we ought not to have done, and we have left undone those things which we ought to have done."

That topographic maps are of considerable commercial importance is shown in a letter of the Chairman of the National Service Committee of Engineers Council to the Secretary of the Interior, appearing in the April, 1919, *Proceedings of the American Society of Civil Engineers.*

"It would require much space to review in any worthy way the needs for and the uses of a complete topographic map. We mention a few merely in order to assert that any one of them is of sufficient importance to warrant all the expenditures necessary to make a complete map. It is obvious that the maps are essential as a basis for National defense, and hardly second in importance is the need of them in connection with the enormous road building programme upon which the Government has entered. The two objects are largely interwoven. Did we have a complete topographic map of the country for use in the execution of our National road

programme alone, the cash saving would exceed the cost of the map. The Federal policy of arid-land and swamp-land reclamation is also responsible for increased appreciation of map necessities, and not less important is the matter of power supply. The Boston-Washington power survey, which you advocated so ably before the Appropriations Committee of the 65th Congress, is merely one of many examples where a complete topographic map becomes a fundamental necessity. In the fields of mining and geology, it has long been known that a map must be the forerunner of all productive work on present-day scale. Finally, in the development and extension of railway systems, which forms one of the most important factors in our National progress, the topographic map has become the greatest single aid, time saver, and means of economy that has been placed in the hands of the constructor. All of these uses and many others of similar purport are of first-class economic importance."

EMPLOYMENT OF DIVISIONAL ENGINEERS.

HEADQUARTERS EIGHTH ARMY CORPS
AMERICAN EXPEDITIONARY FORCES
A. P. O. 931.

MEMORANDUM.

2 Jan. 1919.

INTRODUCTORY.

1. There appears to be a diversity of opinion as to the proper employment in campaign of Division Engineers. Division Commanders have varying ideas on the subject and in no case do the ideas of the Division Commander entirely agree with those of the Corps Commander.

2. The rôle that the Divisional Engineers may be called upon to play in action should be governed by the local situation at the commencement of the battle and thereafter by the situations which arise during the progress of the action.

The Divisional Engineers consist of a regiment of 1,600 men trained in various engineering specialties, and also trained and armed to fight. They are intended *primarily* for engineering work and *secondarily* for emergency fighting. They should always be considered as a last reserve, but not at the expense of necessary engineering work. They should be conscious of the fact that they are combat, as well as construction troops. Each engineer company should comprise four complete working units.

3. The Divisional Engineers should be employed as directed by the Division Commander, who should be advised in the matter by the Division Engineer, G-1 and G-3. The actual direction of their employment should be exercised normally by the Division Engineer, except in certain instances as indicated hereinafter, where units should be placed directly under the orders of an infantry or artillery commander. Whenever engineer units are placed under the direct control of an infantry or artillery Commander, the purpose for which they are to be used should be specified by the Division Commander. The Commander of the engineer unit thus assigned becomes the engineer advisor of the infantry commander.

On account of its equipment and strength, a strong temptation

exists to use the engineer regiment as infantry, thus frequently diverting it from its proper function. Considering the great importance of circulation and supply, the major portion of the engineer regiment should always be designated for roadwork, while a smaller portion may be detailed to prepare the routes for and help the forward movement of the divisional artillery, infantry and machine guns.

In sector warfare the divisional engineers should be assigned to a definite alert position, generally to occupy and defend the second position until the arrival of the troops which the higher command has designated for the permanent defense of this position.

During an engagement the Division Engineer should be constantly on the lookout for opportunities to use the engineer organizations, and he should advise the Division Commander how best to bring the full force of his regiment to bear on the construction work under way, and if necessary, as combat troops against the enemy. Engineer officers with their units ordered to report to artillery or infantry commanders, should keep in close liaison with the latter commanders.

4. Examples of Employment of Division Engineers:

(*a*) At Vaux two platoons of engineers were assigned to a regiment of assaulting infantry. This was correct, as the platoons were definitely ordered to consolidate the position after the assault.

(*b*) At St. Mihiel engineers were assigned to various infantry brigades as wire cutters. The number varied from 100 men to as many as 500 men. This was all right, as the engineers had a definite mission. In general, the assaulting infantry cuts the wire, but the quantities of wire at St. Mihiel were unusual and engineers especially trained for this work were sent forward. In some cases the engineers were trained for two weeks before being assigned to the infantry.

(*c*) At St. Mihiel, one regiment of engineers was split, a batalion being assigned to each brigade. This was not a proper use of engineers because it was not intended by the Division Commander that they be used wholly as infantry; though this is exactly what happened. These brigade and regimental commanders were not trained in the special uses of engineers; the engineers had been given no special training in wire cutting, consequently they were used as infantry. As a result, the Division Commander lost a

division reserve of 1,600 men, and the roads of this division received no attention from the divisional engineers.

(*d*) In the Argonne, in one case, a company of engineers was assigned to each infantry brigade. The brigade commanders did not take their vehicles with them, consequently the engineers were in the way and finally they were used as infantry. By this arrangement the Division Commander lost 500 men of his division reserve and the engineers lost 500 men from road work.

(*e*) In the drive to Sedan, one division assigned its Divisional Engineers to division reserve and gave them orders to do nothing else. As a result, these 1,600 good strong engineers did nothing whatever on the roads for three days, although the roads were greatly in need of work and finally became so bad that this particular Division was unable to get its supplies forward as needed.

(*f*) At Blancmont, a Division Commander assigned the engineers to division reserve and directed that they work on roads until called for by him. As a result, they worked on the roads for six days and finally, in an emergency, the regiment was sent into the line for combat purposes to fill gaps in the line. There is no criticism for this use of engineers.

(*g*) In the Argonne, several Division Commanders directed that their engineers be placed in the division reserve. Either because of direct orders or through failure of the divisional engineers to understand their duties, these regiments remained in division reserve and did nothing whatever on the roads. As a result the traffic conditions became very serious and it is even stated by some that the drive was halted temporarily because of these traffic conditions. This was not a proper use of engineers, as it was a waste of 1,600 men who could have worked on the roads while waiting for the necessity for their employment as fighting troops.

(*h*) In the second Argonne drive, one Division Commander assigned the engineer regiment to the division reserve and directed it to work on the roads until called for. When it was necessary to cross the Meuse River he called for two companies and ordered them to report, one to each infantry brigade, for bridge work. This was an excellent use of engineers, because the Division Commander had them under his control until he decided that two of the companies were needed by the brigades for special engineer work.

(*i*) In the Argonne, one company of engineers was assigned to an artillery brigade to clear the way. This was a good use of the

engineers because artillery vehicles need bridges built for them or roads cleared so that they can advance.

5. It thus appears that the following general rules can be safely followed:

(*a*) Assign no engineers to infantry in an assault except for specific work, such as wire cutting, bridge building, demolition, cutting trails through woods, etc.

(*b*) Assign a few engineers to advancing artillery in an assault.

(*c*) Engineers in division reserve, should be instructed to work on the roads and to be prepared to assemble in a specified place for combat work when alerted.

(*d*) When engineers are assigned specifically for road work, let them know that their services may be required for fighting.

By Command of Major General Allen:

Official: G. C. MARSHALL, JR.
Colonel, General Staff,
Chief of Staff.

Wm. A. Mitchell,
Colonel, Corps of Engineers.

JOHN GRAY FOSTER.

By

Col. W. R. Livermore,

U. S. Army, ret.

John Gray Foster was born May 27th, 1823, at Whitfield, N. H., where his parents were living in straightened circumstances. In 1842, he was appointed a Cadet at the Military Academy at West Point, in the class with McClellan, Couch, Reno, Stonewall Jackson, George H. Gordon, A. P. Hill, and many others who afterward took leading parts in the Federal and Confederate Armies. General Gordon says, ''There seems to be nothing in the condition of his parents, in the surroundings of his family, or in the advantages of his education, to develop, on the one hand, the marked superiority of his mind, or, on the other hand, that genial and courteous bearing, which, even to the last day of his conscious existence, he exhibited to all; so quiet, and yet polished to his equals; so thoughtful and considerate to all. In 1846 he was graduated, promoted to Brevet Second Lieutenant in the Corps of Engineers, and attached to the Company of Sappers, Miners and Pontoniers. He then joined General Scott's Army in Mexico, where he took part in the siege of Vera Cruz and in the battles of Cerro Gordo, Contreras and Churubusco. At Molino del Rey he led the storming column to the point he had previously designated, and was dangerously wounded and carried from the field. Having also a severe attack of dysentery, he was conveyed to his mother's little cottage in New Hampshire, disabled for further service in this war. When he recovered he was employed in work of construction at Fort Carroll, Md., Sandy Hook, N. Y., Forts Sumter and Moultrie, S. C., and Forts Macon and Caswell in North Carolina; at the Coast Survey Office in Washington, and as Principal Assistant Professor of Engineering at the Military Academy. For his services in the Mexican War, he received two brevets; he was promoted to Second Lieutenant in May, 1848; to First Lieutenant in April, 1854; to Captain in July, 1860.

At the breaking out of the Civil War, he was in charge of the fortifications of Charleston Harbor, S. C., engaged in strengthening

the works in anticipation of attack. For the distinguished part he took in transporting the garrison of Fort Moultrie to Fort Sumter he was brevetted Major. After the Fort surrendered, he returned to his work at Washington and at Sandy Hook, N. Y.

In October, 1861, he was appointed a Brigadier General of Volunteers, and soon after took command of a brigade composed mostly of Massachusetts troops and joined Burnside's expedition in North Carolina. The plan for crushing the rebellion was to surround the Confederacy with the Federal Army and Navy, and to cut off supplies from without while the Federal Army advanced, and destroyed the Army and occupied the territory of the Confederates. The Federal Navy held command of the sea, but could not by itself intercept all the blockade runners; a few troops on the Atlantic Coast, however, could keep the ports open to their fleet and closed to the enemy; and if strong enough, penetrate inland, ravage the enemy's fields and cut or harass his communications.

In February and March, 1862, Foster took part in the capture of Roanoke Island and Newberne, and for his gallant conduct received the brevets of Lieutenant Colonel and Colonel. In July, 1862, Burnside was removed to Virginia and Foster was promoted to Major General and placed in the command of the Department of North Carolina with only a handful of men which constituted the 18th Army Corps. During the autumn, his forces being considerably increased, he made incursions throughout the region, driving back the enemy, destroying bridges and doing serious damage to the Wilmington-Weldon Railroad, the great artery which supplied the Confederate Army in Virginia. In these actions Foster's skill, energy and romantic bravery enabled him to defend the position against a greater force of Confederates, and to hold it open as a perpetual menace to their right flank.

President Lincoln was so delighted with his energy and pluck in this campaign, that on the 15th of July he gave him the important Command of Virginia and North Carolina with headquarters at Fortress Monroe. General Gordon says; "Here as well as in the rivers of North Carolina, General Foster displayed great daring in running his boat past formidable batteries." In July, 1863, he says, "I met him upon his return from a gallant dash up the James toward Richmond. With the most extravagant manifestations of pleasure, he told me that he had looked into Fort Darling, run his steamer over torpedoes, four of which, exploding, deluged

his deck, and almost blew him into the water; had received the fire of batteries, open and concealed; and had gone far enough to satisfy himself that the river road to Richmond was yet strongly guarded from river bank to river bottom. General Foster at this time was over six feet in height, and weighed nearly two hundred pounds.''

In the autumn, when Burnside was shut up by Longstreet in Knoxville, Tenn., Foster relieved him. In December, Foster was assigned to the command of the Army and Department of Ohio; from May, 1864, to February, 1865, of the Department of the South with headquarters at Hilton Head. Then he co-operated with Sherman in his march through Georgia and the Carolinas. The first reliable news of his success was sent from Foster's command. In December he opened up communications with Savannah by water. Meanwhile, in 1863, he was promoted to Major, Corps of Engineers. In March, 1865, he was brevetted Brigadier General, U. S. Army, for gallant and meritorious conduct in the capture of Savannah, Ga.; and Major General, U. S. Army, for gallant and meritorious service in the field during the Rebellion. From August, 1865, to December, 1866, he commanded the Department of Florida. In September, 1866, he was mustered out of the Volunteer service and served on fortification and river and harbor work in Massachusetts and elsewhere. He opened up the entrance to Boston Harbor by submarine blasting which presented several novel features.

In Boston, the survivors of the Massachusetts regiments took every occasion to manifest their old affection for their commander and united in praise for the untiring and gallant manner in which he led his command, as well as his tender solicitude for their welfare. To the young officers who were fortunate enough to serve with him, General Foster's magnetism was most invigorating. In the midst of absorbing duties at his desk, he would listen with kind respectful attention to the solicitations of a poor apple-woman, whose tedious story of her woes he could not cut short lest he might seem unsympathetic to her misery. ''Courtesy with him,'' says General Gordon, ''was inborn. It was no deference paid to position and rank, it was a consideration paid to humanity.''

Soon after his return from Mexico Foster was married to Miss Moale of Baltimore, who died soon after the Civil War, then to Miss Anna Johnson of Washington City.

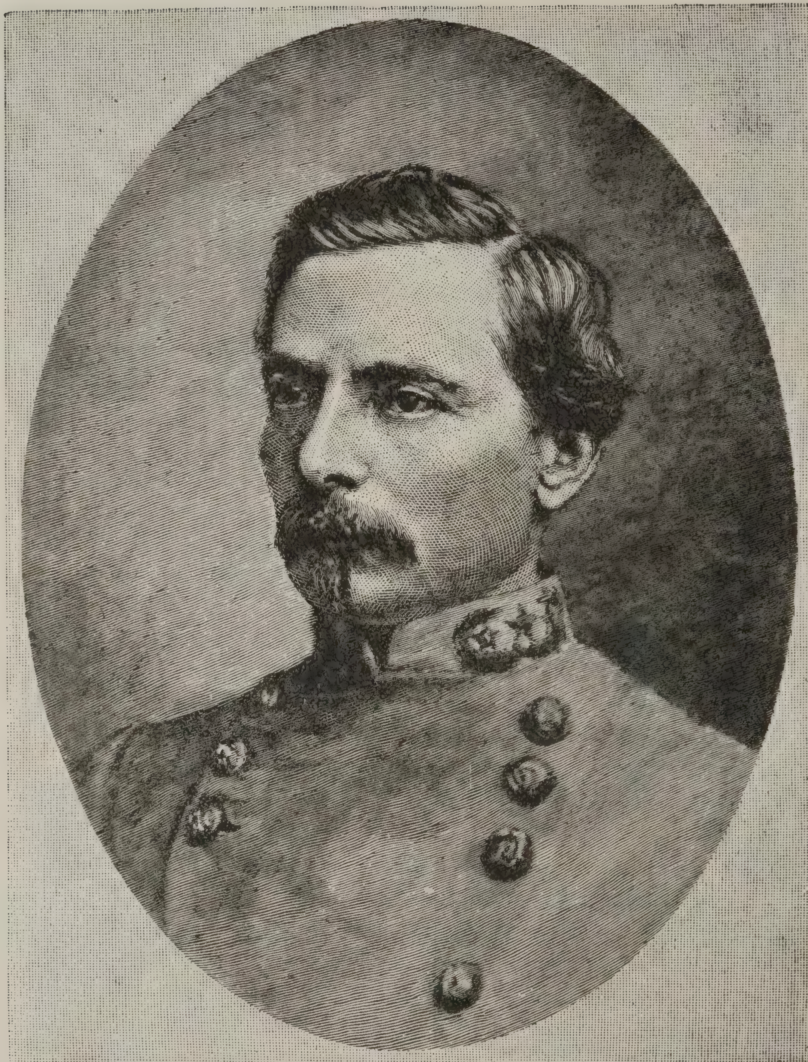
In 1874 he went to the White Mountains for his health, but found the air too bracing. On his way home on the 2nd of September he died at Nashua in a large and handsome house which he had bought for his mother soon after the war.

Foster's operations along the Atlantic were not as conspicuous as those on the great battlefields where the larger armies met, but he did the work assigned to him brilliantly and well. All through the War the Confederate Armies on the Rappahannock or the Potomac had held in check all the forces that the Federals could throw against them. From time to time expeditions were planned to land Federal troops on the Atlantic Coast to turn this line and drive off or capture its defenders. If they had been stronger, Foster's troops, by opening the way, would have materially hastened the collapse of the Confederacy. The enemy so fully appreciated the danger that they kept a larger force than Foster's to guard their flank. The blow, however, fell not from the east but from the west, and it was a great solace to Foster's men that they were ready there also to hold out a helping hand and be the first to announce that the line had at last been broken.

Editorial Note.

The translations recently published in the PROFESSIONAL MEMOIRS on "Old and New Opinions About the Value of Permanent and Fortified Positions," have been very useful in collating these Opinions and in suggesting criticisms on this and related topics of such vital importance to the Service of Military Engineering. We take pleasure in saying that they were written by Lieutenant Colonel Habicht, Editor of the "*Schweizerische Zeitschrift für Artillerie und Genie*," from which they were translated.

THE LIBRARY
OF THE
UNIVERSITY OF ILLINOIS



From Romans Military Operations of Beauregard.
Harper & Bros. By permission.

From a photograph taken in 1865.

G. T. Beauregard
General C.S.A.

IMPROVED TYPE OF GERMAN PILL BOX.

Data by

Lt. Col. J. Edward Cassidy,

Engineers, U. S. A.; 317th Engineers, First Army Corps.

The concrete "pill box" described herewith was undoubtedly the last one ever built by the Germans, and contained a number of unique features. This "pill box" was built in the lower part of the Argonne Forest as a support to the last element of the Hindenburg Wotan Line, and as near as could be determined had been constructed after July 1, 1918. While the structure proper had been completed, excepting some little work in the main entrance, the deep gallery shelter had not been entirely completed. The work clearly indicated that it was of recent origin and pencil memoranda made by a detachment of the 30th Pioneer Regiment (German) placed the date of construction after July 1. Memorandum sketches also indicated that this "pill box" was the first of a complete chain that was to extend through the lower part of the Argonne, the work being stopped short by the attack of September 26, 1918.

The following points are to be particularly noted in connection with this "pill box":

(*a*) Thickness of walls and roof, and heavy reinforcement of the concrete.

(*b*) Openings for machine guns to provide flanking and frontal fire. Arrangements were made for mounting two machine guns each in openings No. 3 and No. 5 (the latter being the main entrance). Leading from each of the machine gun openings was a path, one path for each gun—as shown by the accompanying illustrations—two paths radiating from openings No. 3 and 5, making a total of seven paths. In the attack of September 26, the machine gunners in this "pill box" were handicapped by the fact that no fire could be brought to bear directly in front of the "pill box," as a result there was a large dead space between the field of fire of the guns in openings No. 2 and 3. The complete system of "pill boxes" was laid out so as to provide for the area directly in front of any one unit to be swept with fire from the adjoining "pill boxes" on

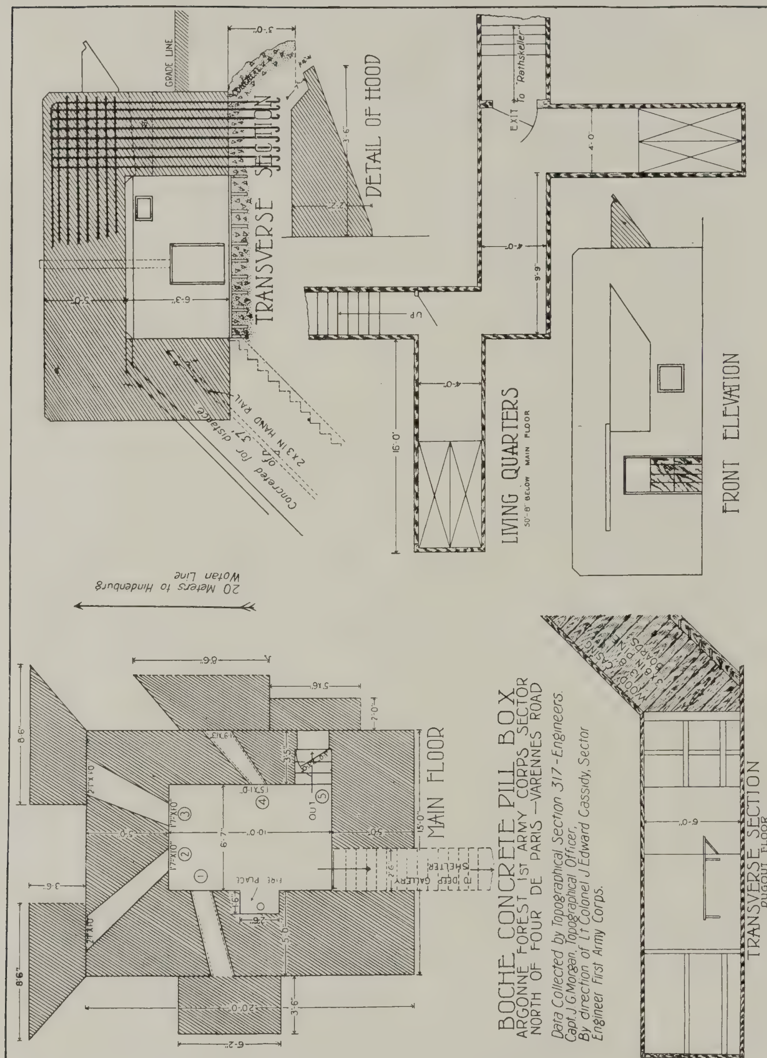

BOCHE CONCRETE PILL BOX
ARGONNE FOREST 1ST ARMY CORPS SECTOR
NORTH OF FOUR DE PARIS —VARENNES ROAD
Data Collected by Topographical Section 317-Engineers.
Capt J G Morgan, Topographical Officer,
By direction of Lt Colonel J Edward Cassidy, Sector
Engineer First Army Corps.
MAIN FLOOR
FIRE PLACE
DEEP GALLERY
SHELTER
OUT
20 Meters to Hindenburg
Wotan Line
TRANSVERSE SECTION
GRADE LINE
2x3 IN HAND RAIL
Concreted for distance of 37'
DETAIL OF HOOD
LIVING QUARTERS
50'-8" BELOW MAIN FLOOR
UP
EXIT to "Rathskeller"
FRONT ELEVATION
TRANSVERSE SECTION
DUGOUT FLOOR

Fig. 1.

each flank. As this was the only unit of the system ever completed, there were no supporting units on the flanks.

(*c*) Paths were cut entirely across the plateau on which this "pill box" was built, so that roads and positions on other hills were commanded by the fire from this unit.

(*d*) The gallery leading from the interior of this "pill box"

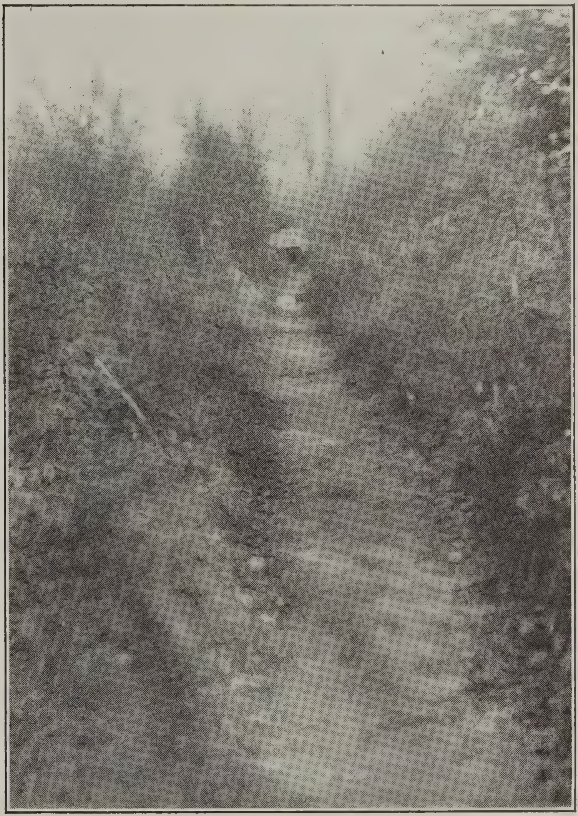


Fig. 2.

to the deep shelter was concreted to a distance of 37 feet from the floor of the "pill box," the remainder of the gallery being cased with standard wood casing.

(*e*) The ingenious arrangement of "hoods" over each machine-gun opening will be noted, the object being to protect the gunners from the flare of bursting shells. These "hoods" were heavily

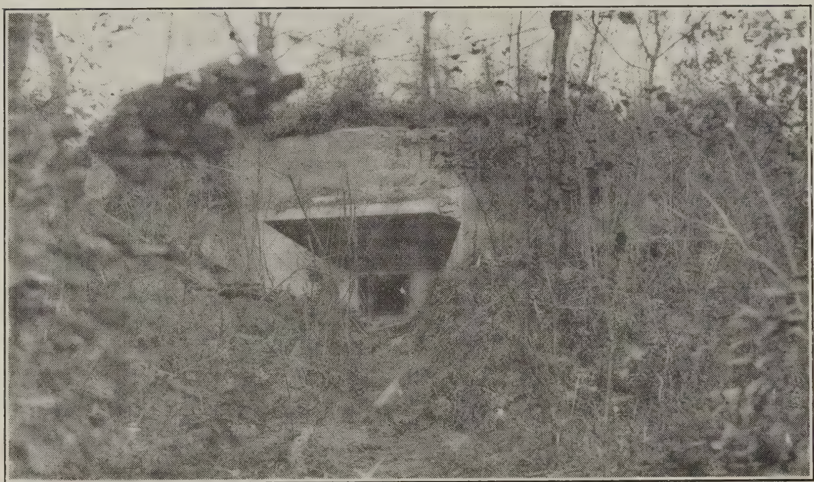


Fig. 3.

Fig. 4.

reinforced, and quite complete in detail, even to a groove for a water drip to prevent water running down the underneath slope of the "hood" and into the "pill box." It will be noted from the illustrations that direct hits had been made on this "pill box," one on the corner of the "roof" (either a 149 mm. or a 155 mm. H. E. shell), and the other on a corner of the "hood" over opening No. 4 (either a 75 mm. or a 77 mm. shell).

(*f*) A fire place was constructed as an integral part of the left flank wall, and a stove pipe concreted in when the roof was constructed.

(*g*) The two machine guns in each of the openings, No. 3 and

Fig. 5.

No. 5, were arranged so that one man operated each pair of guns.

(*h*) This "pill box" was heavily mined and wires run back about 150 yards so that the structure could be blown up if the gunners were forced to withdraw—the idea seemed to be that in case the gunners were driven out, they would retire by the way of the deep shelter, out through a rear exit, and blow up the "pill box" from a safe distance as they retired. A broken wire prevented the "prearranged plan" being carried out. The mine, which was charged with 40 kilograms of *Sprengpatrone* was removed and destroyed under the direction of the writer. *Sprengpatrone* can not be detonated by ordinary Tetryl caps, but is detonated by small blocks of more sensitive compounds. In this particular case, the

detonator consisted of four small cubes of explosive apparently the same as our TNT, with a cap similar to our Tetryl cap in each of the four blocks. It appears that the Germans were great believers in multiple detonators, as, in a large number of mines rendered harmless by the writer, at least two separate detonators were used, and in a great many cases three or four.

(*i*) The roof camouflage consisted of the actual transplanting of some of the surrounding shrubbery, making an almost perfect concealment from aerial observation.

(*j*) The steel reinforcement consisted of round rods approximately .75 inch in diameter, bent and shaped in various ways. These rods contained a higher percentage of carbon than our standard reinforcing rods.

(*k*) The deep gallery shelter contained four bunks, though the manning of all the guns required a crew of five men. There was a "rathskeller," about 50 feet in the rear of the "pill box," which was also the rear outlet from the deep shelter. This "rathskeller" was protected by steel plates and sections of Decauville track, and it is believed that the N. C. O. in charge of the gun crew lived in it except during a bombardment.

(*l*) For some reason, the right flank wall was but 3 feet 5 inches thick as against 5 feet for the other walls and roof. The explanation of this difference was not apparent.

(*m*) The entrance into the "pill box" from the ground level is approximately 3 by 3 feet with concrete steps leading down to the floor level inside the "pill box." This entrance was protected by a "hood" also. The method of entering seemed to be to sit down and slide feet first into the doorway. This entrance, during active operations, was protected by an armor-plate shield with machine gun ports for two guns in same.

"Adobe" Shot with Grade III TNT on Boulder.[1]

REPORT TO BUREAU OF MINES, DEPARTMENT OF THE INTERIOR.

By

Mr. J. E. Tiffany,
Explosives Experiment Station.

For the purpose of demonstrating the availability of Grade III TNT for the purpose of breaking up boulders, a sand-stone boulder was selected. The boulder was 6 feet long, 3 feet wide and 1½ feet thick. Two-thirds of its under surface was supported on ground, while the balance of it projected over the bank of a small stream; the longer axis of the boulder was approximated parallel to the direction of the stream.

A cartridge of M-2328 (Grade III TNT) was prepared with newspaper wrapper; size of cartridge was 1¼ inch by 6 inches.

A No. 8 electric detonator (M-2323) was inserted centrally in the end of the cartridge. The cartridge was laid centrally on the upper surface of the boulder and then loose Grade III TNT piled over the cartridge. The total charge of explosive in the cartridge and loose was 1½ pounds. The charge was covered with a piece of paper, which was in turn covered with clay, approximate thickness, 2½ inches.

The charge was fired with a push-down blasting machine.

As a result of the explosion, the boulder was shattered to greater or less extent throughout its entire mass. The largest piece was broken from the projecting side of the boulder and measured approximately $2' \times 2' \times 1'$. The next largest piece was about 1½ feet square and 6 inches thick. Probably 40 per cent of the boulder was broken into fragments 2 inches and less.

CONCLUSIONS.

This one trial demonstrated the possibility of using Grade III TNT for breaking up boulders.

For boulders of a similar nature and size, less explosive should be used.

---

[1]Published with the permission of the Director of the Bureau of Mines.

Report of Tests to Demonstrate the Adaptability of Grade III TNT for Clearing Land, or Similar Uses.[1]

REPORT TO BUREAU OF MINES, DEPARTMENT OF THE INTERIOR.

By

Mr. W. J. Montgomery,
Junior Engineer.

Shot No. 1. A solid oak stump approximately 3 feet in diameter and standing 18 inches out of the ground was selected January 24, 1919. The stump was rooted in wet clay on a slight slope, the roots being distributed and the charges placed as in Figure 1. The charges were placed 4 feet below the surface of the ground in bore-holes approximately 2 inches in diameter, bored in the clay with an earth auger. The charge consisted of 7 pounds of Grade III TNT (M-2328), 1¾ pounds to the hole. The legs of the electric detonators in the primers were connected in series. In one of the bore holes the charge was loaded into 8 to 10 inches of water, remaining there perhaps 10 minutes.

When the shot was fired, a muffled report was heard and the characteristic dark-gray smoke cloud observed. The stump was split into three major pieces. These were thrown possibly 10 feet in the air, falling back into the crater formed by the shot. The crater measured 10 feet in diameter and 4 feet deep. The lateral roots seemed to be well taken out. Although there was a moderate amount of débris thrown, no large missiles were thrown to any great distance.

Shot No. 2. To demonstrate the use of Grade III TNT in splitting logs, two oak logs, each 6 feet long, were selected. The first one (January 21, 1919) was 39 inches in diameter. It had about the average number of knots, was of fairly straight grain, and quite solid. A 2-inch hole was bored midway between the ends and about 2 inches beyond the center of the log. This was loaded with 4 ounces (114 grams) of Grade III TNT (M-2328).

When the shot was fired practically no report was heard and

---

[1]Published with the permission of the Director of the Bureau of Mines.

very little smoke observed. The stemming was not blown out of the bore-hole. The log was split, except for a few strands at the bottom. The splitting was readily completed with a pinch-bar. There was very little chambering, practically no timber being wasted. The plane of cleavage was roughly coincident with the axis of the bore hole.

Shot No. 3. The second log (January 24, 1919) was the butt of the tree, and the ends were 44 inches and 40 inches in diameter. This log was solid with few knots and straight-grained. The bore hole was placed as in the previous log and charged with 5 ounces, 142 grams of Grade III TNT (M-2328).

When the shot was fired, a dull report, not loud, and a little smoke were observed. The stemming was blown out of the bore hole. The log was split in two pieces, the plane of cleavage being

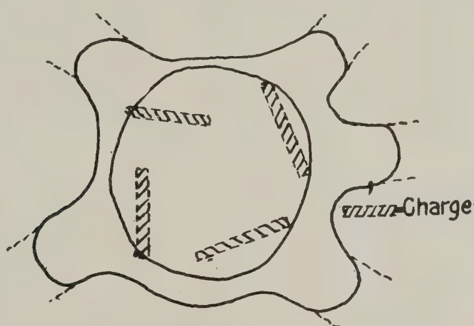


Fig. 1.

coincident with the axis of the bore hole. A chamber, 6 inches long by 4 inches in diameter, was formed. There were no fragments thrown in either shot.

Shot No. 4. To demonstrate the use of Grade III TNT in breaking boulders by adobe shots, or bulldozing, a trial was made on a sandstone boulder on January 24, 1919. The boulder was roughly elliptical, $6' \times 5' \times 1'$ thick, and was resting on a flat surface of sandstone. One pound of Grade III TNT (M-2328) was placed on the center and covered with approximately 5 inches of moist clay.

When the shot was fired, a sharp report, a small flame, and a small amount of dark smoke were observed. About one-half of the rock was broken into sizes that could be easily handled as they were; the other half retained its original shape, but was thoroughly cracked. After 3 minutes work with a 16-pound sledge, the entire boulder was in shape to handle.

In all shots, the TNT was packed in newspaper into 1¼-inch cartridges in the usual manner, the explosive being jarred down. All shots were fired with a push-down blasting machine. All primers were made with a No. 8 electric detonator (M-2323) which was fastened into the end of the primer with string in an approved manner. Moist clay was used in all cases for stemming.

There was no indication of incomplete detonation in any shot.

Moving pictures and snapshots were taken of shots 1, 3 and 4.

These were fired in the presence of Director Van H. Manning; Supervisor of Stations, D. A. Lyon; Explosives Engineer, S. P. Howell; Safety Engineer, M. F. Leopold; and Chief Coal Mining Engineer, J. W. Paul.

CONCLUSIONS.

1. That Grade III TNT can be used for such purposes as shooting stumps, splitting logs and breaking boulders.

2. That the stump blasted (Shot No. 1) was slightly overloaded.

3. It seems possible that the number of bore-holes under a stump of the type of Shot No. 1 might be reduced to three or, in some cases, even less.

4. That No. 8 electric detonators seem to insure complete detonation.

5. It seems probable that a smaller auger than 2 inches might be used to bore the holes for splitting logs, thus saving time and labor.

6. That in adobe shots on large flat boulders, better results might be secured by using the same weight of explosive, but placing it in two or more charges symmetrically distributed.

Report on Shot of Grade III TNT Under Water.

REPORT TO BUREAU OF MINES, DEPARTMENT OF THE INTERIOR.

By

Mr. W. J. Montgomery,[1]

Junior Explosives Engineer.

On March 14, 1919, a stump was shot in the Bureau's Experimental Mine near Bruceton, Pa.

A bore-hole 1½ inches by 42 inches deep was drilled vertically in the floor. The first 13 inches was drilled through coal, the next 4 inches through limestone, and the rest of the distance in fire clay, which is about 4 feet thick at this point. The top of the bore-hole was about 4 inches under water.

As it was desired to secure the maximum effect, the bore-hole was overloaded. The charge consisted of approximately 2 pounds of Grade III TNT (M-2328) made up into 1¼-inch newspaper cartridges in the usual manner. The charge was primed with a No. 8 electric detonator (M-2323). These were loaded into the bore-hole with sufficient pressure to break up the cartridges. No tamping was used as the shot was under water, although a piece of limestone was forced into the bore-hole to prevent any of the charge from floating to the surface. A small amount of explosive was lost by being carried away by the water.

After being loaded, a wait of approximately 15 minutes was necessary to locate a break in the firing line. When the shot was fired, a loud report was heard. No observation was made as to whether or not a flame was visible.

A dark heavy smoke cloud was formed. As the shot was fired at the face of a butt entry and the ventilation was consequently poor, no attempt was made to observe any indications of incomplete detonation until the next day. As water was flowing through the sump all night, the accuracy of observation for indications of incomplete detonation was questionable. No indication was found. A crater, 4 feet in diameter and 42 inches deep, was formed. Con-

[1]Published with the permission of the Director of the Bureau of Mines. Approved: S. P. Howell, Explosives Engineer.

siderable other material was loosened so as to be easily removed with a pick.

No samples of mine air were taken.

CONCLUSIONS.

1. That immersion of Grade III TNT under 3½ feet of water for 15 minutes does not prevent detonation.

2. That a No. 8 electric detonator seems to be sufficiently effective to insure detonation.

Report on Breaking Concrete Piers with Adobe Shots of Grade III TNT and 40 Per Cent Straight Nitroglycerin Dynamite.[1]

REPORT TO BUREAU OF MINES, DEPARTMENT OF THE INTERIOR.

By

Mr. A. B. Coates,

Explosives Experiment Station.

The old ballistic pendulum piers left by the Explosives Section of the Bureau of Mines at the Arsenal Grounds, 40th and Butler Streets, were removed to make more room for the War Department. It was the original intention to blast these piers down with TNT alone, and to note its suitability for this class of work. Before the work was completed the supply of TNT was used up, and it was then decided to finish the work with our 40 per cent standard dynamite in order to get a comparison of the TNT with the standard.

The size of piers is shown by the three views, Fig. 1. The concrete was hard and apparently of good quality. Both piers seemed to be in the same condition as regards quality and cracks. This was demonstrated in results of blasts where TNT was used on both piers. In the first three blasts of TNT on the West pier 52 pounds of explosive were used breaking up 40 cubic feet concrete, and in the first three blasts of TNT on the East pier 6 pounds of explosive were used, breaking up 40 cubic feet concrete. There were very few cracks in the concrete, except as shown in Fig. 1. These cracks were due to the concrete having been poured in layers, each layer having become partly set so that the next layer did not bind firmly to it. These layers, of course, made the work of breaking up much easier than if the piers had been monolithic.

All shots were "adobe" shots, with 2 or 3 shovelsful of moist sticky clay firmly plastered over the explosive.

All charges were placed on top with the exception of the first blast, which was placed in two charges on the side.

The TNT was fired with No. 8 electric detonators and the dynamite with No. 6 electric detonators. All TNT was fired in news-

[1]Published with the permission of the Director of the Bureau of Mines.

paper cartridges and all dynamite was fired in original wrappers.

Following is a chronological record of blasts fired with results:

January 27, 1919: weather clear; outside temperature about 45° F.

In the following all weights given are net of explosive, exclusive of paper wrapper.

1st Blast: 32 pounds TNT placed on East side of West pier in two charges of 16 pounds each. The center of each charge was 31 inches from top of pier, and 28 inches in from the end. The cartridges and clay were supported on boards.

Result: Pieces from each end of top layer, 14½ inches thick and 28 inches long, were broken loose, so that they were removed with a bar. Pier was cracked in several places and old cracks made more pronounced.

2nd Blast: 0.5 pound TNT on top in center of the remaining 5 foot 4 inch slab.

Result: Slab broken up so it was easily removed with bar.

3rd Blast: Three ½-pound charges TNT on top, one in center and others 20 inches from ends.

Result: Concrete broken down to third layer, 27½ inches from top.

4th Blast: Three ¾-pound charges TNT placed as in 3rd blast.

Result: The 25-inch layer was broken up so it was easily removed with bars.

5th Blast: Same as 4th.

Result: All of the 12-inch layer broken and also part of the bottom 21-inch layer split off to ground, leaving a slab above ground 20 inches high, 40 inches wide, and 7½ feet long.

6th Blast: Two ½-pound charges TNT on top of slab, 20 inches from ends.

Result: The slab split lengthwise to width of 30 inches and reduced in height to 10 inches, length unchanged at 7½ feet.

No other TNT blasts were used on this pier.

Summary for West pier with TNT:

In the six blasts a total of 10.7 pounds of TNT was used removing 159.5 cubic feet of concrete, or 14.9 cubic feet per pound of TNT.

Blasting on the East pier with TNT was now started as follows:

1st Blast: Three charges of ½ pound each on top, one in center and other 20 inches from ends.

Result: The top 14½-inch layer was broken up, so it was easily removed.

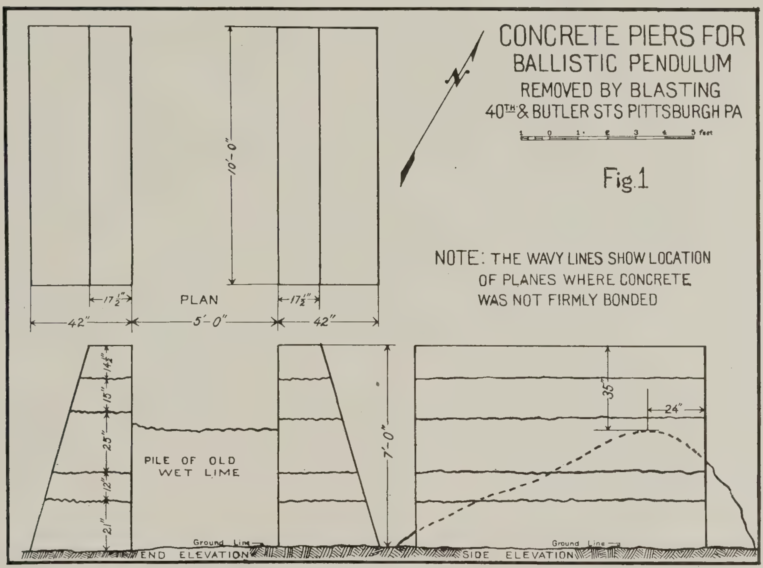


Fig. 1.

2nd Blast: Three charges of 1 pound each, placed as in first blast on this pier.

3rd Blast: Three charges of ½ pound each, placed as in first blast on this pier.

Result: Everything easily removed down to top of third layer, 28 inches from top.

Summary for TNT on East Pier:

In the three blasts a total of 6 pounds of TNT was used removing 40 cubic feet of concrete, or 6.67 cubic feet of concrete per pound of TNT.

January 28, 1919: Weather clear; temperature about 45° F. Work was now started with 40 per cent straight nitro-glycerin dynamite.

7th Blast on West pier: Three charges, of one stick each, on top of bottom slab. Total weight of charges, 1.2 pounds. One charge in center, others 18 inches from ends.

Result: The $10'' \times 30'' \times 7\frac{1}{2}'$ slab was broken up, so it was removed with bars and picks.

Summary for dynamite on West pier:

In this one blast 15.5 cubic feet of hard concrete was broken up with 1.2 pounds explosive, or 12.9 cubic feet per pound of 40 per cent dynamite.

Blasting on East pier was now started with dynamite.

4th Blast: Three charges of two sticks each, one in center and others 20 inches from ends. Weight of dynamite 24 pounds.

Result: The 3rd, or 25-inch, layer of concrete was broken in pieces so it could be removed with bars.

5th Blast: Three charges of one stick each placed as in above blast, broke up the 12-inch layer. Weight of dynamite used 1.2 pounds.

6th Blast: Three charges of three sticks each, placed one in center and others 24 inches from ends. Weight of explosive used 3.6 pounds.

Result: Large pieces on each end broken off and balance of pier badly cracked.

7th Blast: Two charges of two sticks each placed in holes dug in longitudinal crack. Weight of explosive 1.6 pounds.

Result: Slab broken up so pieces were removed with bars except large piece on south end.

8th Blast: One charge of two sticks placed in hole 4 inches deep. Weight of charge, 0.8 pound.

Result: The piece was cracked up and was removed with bars and picks.

Summary for 40 per cent dynamite on East pier:

In the 5 blasts a total of 9.6 pounds of explosive was used breaking up 135 cubic feet of concrete or 141 cubic feet of concrete per pound of 40 per cent straight nitro-glycerin dynamite.

Summary of totals:

In the 9 blasts of TNT, a total of 16.7 pounds was used breaking up 199.5 cubic feet or 11.9 cubic feet of concrete per pound of TNT.

In the 6 blasts of dynamite, a total of 10.8 pounds was used, breaking up 150.5 cubic feet, or 13.9 cubic feet per pound of 40 per cent standard dynamite.

CONCLUSIONS.

As a result of this work, it appears that our 40 per cent standard dynamite broke up 2 cubic feet per pound more of concrete than Grade III TNT. In this test, however, the dynamite had the advantage, due to the fact that three blasts of TNT were fired on the East pier before it was decided to use the dynamite for a comparison. These three blasts of TNT undoubtedly cracked up the pier to some extent and made it easier for the following shots of dynamite. Then again, two blasts of dynamite were shot in holes about 4 inches deep and these shots, due to better confinement, broke probably more concrete than a straight ''adobe'' shot would.

It thus appears from the results of this one test that there is no practical difference in the efficiencies of grade III TNT and 40 per cent straight nitro-glycerin dynamite when used in ''adobe'' shots to break up concrete.

Report of Tests to Determine the Adaptability of Grade III TNT For Shooting Oak Stumps.[1]

REPORT TO BUREAU OF MINES, DEPARTMENT OF THE INTERIOR.

By

Mr. W. J. Montgomery,

Explosives Experiment Station.

To test the efficiency of Grade III TNT as a stumping powder, trial shots were made on January 17 and 20, 1919.

On January 17, 1919, an oak stump approximately 3 feet in diameter was selected. The stump was solid and rooted in wet clay on a slope pitched approximately 5 per cent. The stump stood 2 feet out of the ground. There were five main lateral roots and one main tap root, distributed as shown in Fig. 1.

The charges were located as shown in Fig. 1. Charges 1, 2, 5 and 6 were placed 4 feet, while charges 3 and 4 were placed 3 feet below the surface of the ground. The charges consisted of 1½ pounds each of Grade III TNT (M-2328), giving a total weight of explosive of 9 pounds. When the shot was fired, a fairly loud report, somewhat muffled, was heard and a moderate amount of low lying dark gray smoke was given off. The stump was broken into two major pieces, about equal in weight. These were thrown to an estimated height of 50 feet, falling to earth 34 feet and 64 feet, respectively, from their original position. Smaller fragments and pieces of clay were thrown, possibly, 100 feet in the air. A crater, practically circular, 12 feet in diameter and 4 feet deep was formed. The lateral roots were well torn out, in some cases 4 feet back from the edge of the crater.

The next stump selected (January 20, 1919), was an oak stump 3 feet in diameter standing 2 feet out of the ground, which was fairly level. The soil was a mixture of clay and sandstone fragments. The stump was solid, except that one part had been split in felling the tree. This part was firmly rooted. The roots were distributed as shown in Fig. 2. The charges were located as shown in Fig. 2. Charges 1 to 7, inclusive, were approximately 4 feet, and charge 8 3 feet, below the surface of the ground. Each charge consisted of ¾ pound of Grade III TNT (M-2328).

---

[1]Published with the permission of the Director of the Bureau of Mines.

When the shot was fired, a muffled report was heard and the characteristic low-lying dark-gray smoke observed. The stump broke into four pieces, two large and two small. The two large

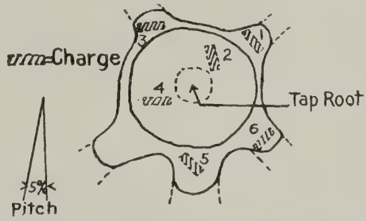


Fig. 1.

pieces were torn loose and overturned at the edge of the crater. One of the small pieces was thrown approximately 75 feet. The other—that is, the portion marked "A" in Fig. 2 remained in the

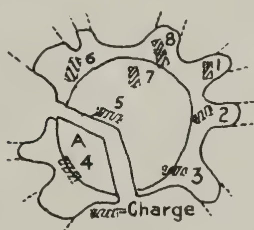


Fig. 2.

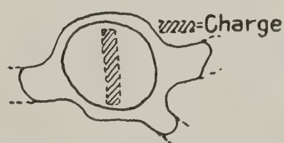


Fig. 3.

ground. It was loosened, however, so that it could easily be taken out. A crater $10' \times 6' \times 3'$ deep was formed. The flying fragments were few and did not travel far. The charges were placed in the

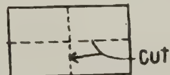


Fig. 4.

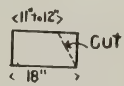


Fig. 5.

bore holes, which were very wet, and allowed to remain 1½ hours before the shot was fired.

A third oak stump, 18 inches in diameter, was next selected. The stump stood 18 inches out of the ground. The stump was solid, but had remained in the ground until most of the smaller roots had

rotted off. The stump was rooted in wet clay. The ground was fairly level. One charge of 2 pounds Grade III TNT (M-2328) was located as shown in Fig. 3. The charge was approximately $3\frac{1}{2}$ feet below the surface of the ground.

When the shot was fired, a muffled report was heard and the characteristic low-lying dark-gray smoke again observed. The stump was split in two pieces which were torn loose and overturned at the edge of the crater. The crater was $6' \times 4' \times 3'$ deep. Practically no fragments or dirt were thrown more than 20 feet.

Three-foot oak stump before shot, showing charge—6 pounds Grade III TNT.

In all the shots, the bore-holes were made with a coal auger, bore-holes being approximately 2 inches in diameter. The holes were bored into the ground, no attempt being made to bore into the roots.

The explosive was loaded into $1\frac{1}{4}$-inch cartridges, made up in the following manner: A double sheet of newspaper was cut into 4 equal parts as per Fig. 4. Then the corner was cut off each point as per Fig. 5. These were rolled in a $1\frac{1}{4}$-inch cartridge stick, the explosive loaded into the shell and jarred down. Packed in this way, the cartridges weighed about 1/3 pound each. In loading the cartridges in the bore holes the cartridges were tamped in the bottom, enough pressure being used to break the cartridge. The last

cartridge in each bore hole was primed with a No. 8 electric detonator (M-2323). The primer was placed in the end of the cartridge and fastened in place with string. The holes were tamped firmly with wet clay. The legs of the electric detonators were connected in series and fixed with a push-down blasting machine of the usual type.

In no case was there any indication of an incomplete detonation.

Result of blast on 3-foot oak stump shot with 6 pounds Grade III TNT.

CONCLUSIONS.

1. That oak stumps can be blasted with Grade III TNT.

2. That while stump (1) was overcharged, stumps (2) and (3) were loaded with approximately the correct weight of explosive.

3. If tractor or other stump pulling apparatus is to be used, the charges could be much smaller.

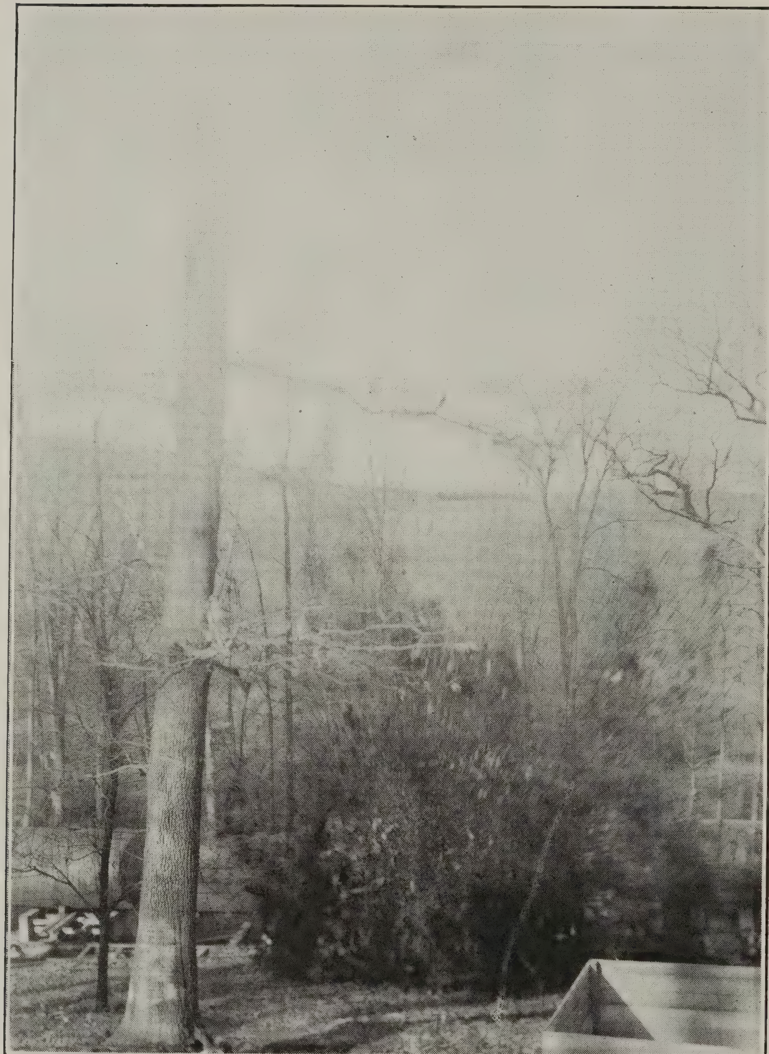
4. It seems probable that the number of bore holes and consequent expense for labor and detonators might be materially reduced for stumps of the type of (1) and (2).

5. That exposure of the explosive for a short time, *i. e.*, an hour, to the moisture in a wet bore hole does not materially reduce its efficiency.

6. That a No. 8 electric detonator seems to be strong enough to insure detonation even in wet bore holes where the exposure has not been prolonged for over an hour.

Result of blast on 18-inch oak stump shot with 2 pounds Grade III TNT.

Crater formed by 9 pounds of Grade III TNT in shooting 3-foot oak stump.



The blast. A 3-foot oak stump shot with 6 pounds Grade III TNT.

German Traps and Land Mines.

From a captured German Document (undated).

Forwarded by the Military Intelligence Division, U. S. Army.

Tank Mines.

Dimensions in meters.

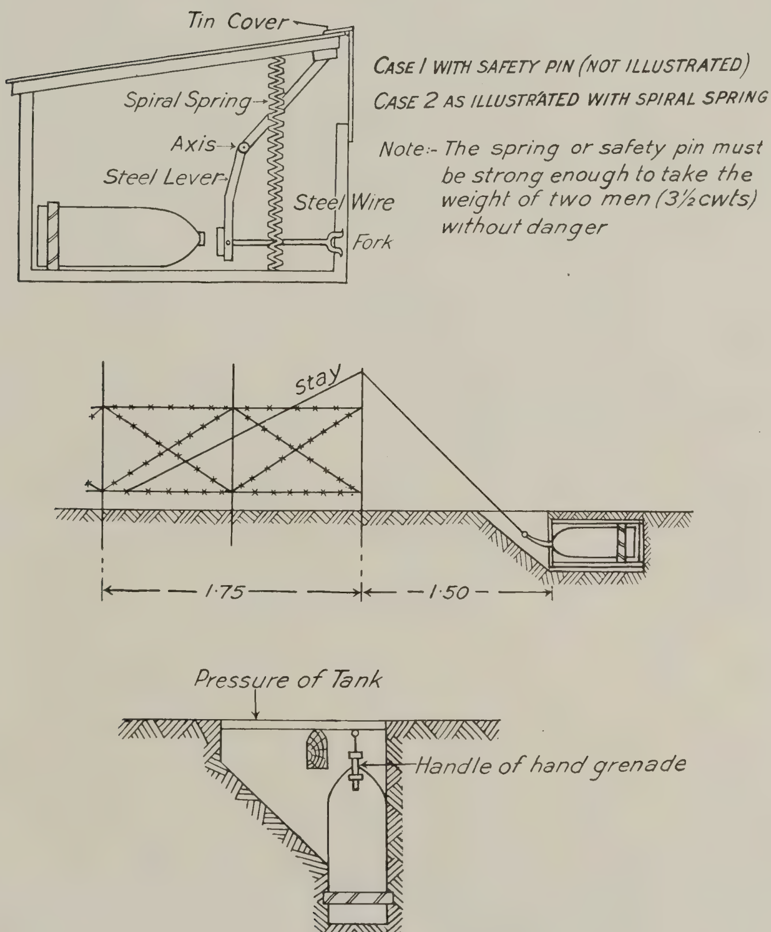
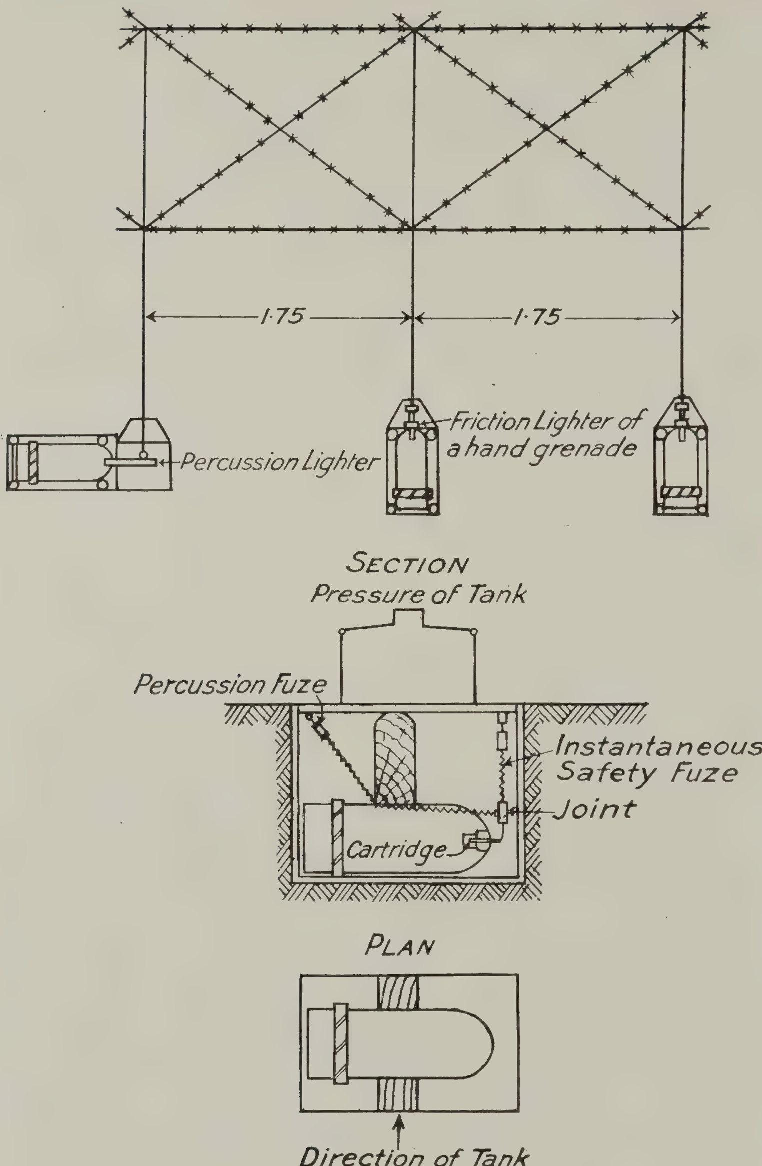


Fig. 1.



General Staff (Intelligence),
General Headquarters.
19th November, 1918.

Fig. 2.

HIGH-BURST RANGING.

By

Lieut. Montague Blundon,
74th Engineers.[1]

High-Burst Ranging may be defined as the observation and determination of the position of the premature burst of a shell, in the air, near a predetermined point on its trajectory; and the computation of the theoretical point of impact of the prolongation of this trajectory in relationship to the target. Obviously, the method is only employed when the target can not be seen on account of defilade, wooded country, or when a low lying mist covers the target, but not the observation posts, or on account of other reasons which make the target obscure, such as the bursting of numerous shells in the vicinity of the target. One of its principal advantages, too, is that it can be used to probably better advantage at night than in the daylight hours. The principle was inaugurated during the war, and it appears to be generally accepted that the Germans were first to make use of it.

This report deals with this system of ranging, and its purpose is to give a summary of such methods as were developed in the A. E. F., together with some general comment on the subject. For convenience of arrangement, the data is submitted under the following captions:

I. General Remarks;
II. Systems;
III. Instruments and Operations;
IV. Reports and Manuals.

I. GENERAL REMARKS.

There seems to be no data available as to any special investigation of this subject in the Engineer camps and schools of this country, nor does it appear that either branch of the Artillery

[1]Formerly 2d Battalion 29th Engineers, Flash and Sound Section.

paid any particular attention to its development in the American Training Schools, except during the last few months of the war. On the other hand, in both branches of the service, Engineers and Artillery, the practice appears to have been to train observation units only along elementary lines, and to leave to the better equipped technical schools in France and in England the detailed study and training.

The first impetus to investigate this subject appears to have been received through the apparent success of its employment by the Germans, though just what particular method they used has not as yet been made clear. The general belief, however, is that their method was a most efficient one, and that they obtained excellent results from it. In the translation, though, by British "Maps" of *Vorschrift fur Artillerie Messtrupps*, Vol. I, December, 1917, is given a general outline of the principles involved, but there does not appear any detailed account as to just what portion was embraced in the German methods.

This system of ranging is still very much in the experimental stage in the American Army, for it is felt that no method should be decided upon until comparitive trials are made by actual observations on bursts, at an Artillery range, under varying conditions, in order to determine the degree of accuracy of the various systems and methods which have already been suggested. Such experimentation will, too, undoubtedly, lead to many changes in the methods that have already been tried.

In the A. E. F., the Flash sections of the Engineers (1st Battalion 74th Engineers, formerly 2nd Battalion 29th Engineers) gave considerable attention to this form of ranging, but the only type of instrument available by these sections was by no means satisfactory, though they had, of necessity, to be employed until such time as a more suitable and accurate instrument could be designed and obtained. Very little progess, therefore, was made in this system of ranging by the Flash units. With the improvements, though, that are surely to be made in the instruments and equipment of such sections, it would certainly seem that some method of high-burst ranging, much simpler in form to most of those now in vogue, will, in the future, be put into practice by such units.

The high-burst ranging by the Flash sections was, however, secondary to their other fields of efforts, which included, primarily

the "spotting" and locating of the enemy's guns, and information about their activity, and the collecting of all intelligence about the enemy's movements, balloons, planes, trains, working parties, etc., and, indeed, any information that would be of value to our own forces. There were, as will shortly be mentioned, other American observation units whose sole purpose was high-burst ranging.

In all of the ranging sections employed at the front the universal practice was to compute the prolongation of the trajectory, from the point of burst of the ranging shell, to its theoretical point of impact; and to give the results to the batteries in "longs, shorts, rights, and lefts." In the future, though, most of this computation may, perhaps, be delegated to the battery commander, so that the ranging duties of the observation units will be confined principally to obtaining and submitting results merely on the locations of bursts. This then, would greatly simplify the work of the Flash sections. Further on in this report, under "Suggestions," is given the preliminary plans now being considered for the development of this system of observations.

In the field of operations in the A. E. F., the Engineer units were the first to take up the actual ranging by high-burst methods. But, as has just been mentioned, their efforts were greatly handicapped by the poor class of instruments with which the Flash sections were equipped. The subject was, too, naturally, of the greatest interest and importance to both branches of the Artillery, and the Coast Artillery, especially, soon began an investigation and study of the various systems. For the most part the Engineer personnel obtained its training from the English sections, though some French methods were also adopted.

During the latter months of the war interest in the subject grew in intensity, and during the summer of 1918, the Heavy Artillery School had detailed a number of officers to study at a French school in the southern part of France. Afterwards, a High-Burst Ranging School was started, under the auspices of the Heavy Artillery School at Angers. The Engineers, too, were continuing their study of the subject, and it soon became apparent that some division should be made in the allotment of such service with the Army Corps by the Artillery Information Service. The matter was taken up in conference, and the result seems to have been that the Heavy Artillery should provide its own ranging sections, and that the Flash sections should continue ranging for the Field Artillery along

more elementary lines, adaptable to the class of instruments with which they were provided. So, as opportunities were presented, the Flash sections continued to range from time to time for the A. I. S., both for percussion fire and for high bursts, but, just at this time, no reports are available as to the results secured.

In September, 1918, two Engineer officers from the Flash and Sound School at Fort St. Menge, were detailed to study the telemetric system for adjustment of fire, and, later, these two officers were sent to the front to observe this system in operation.

In October, 1918, the Heavy Artillery put into operation on the Verdun front the first Provisional High-Burst Ranging Section, with its P. C. at Belleville, lying just to the north of the city of Verdun. This section followed the telemetric system of adjustment, and it was here that the two Engineer officers reported. The section was attached to the 30th Brigade Railroad Artillery Reserve, and its scope of operations was limited to the adjustment of fire only for the batteries of this brigade. As this was the only purely high-burst ranging section that was ever installed on any of the American sectors, it is thought proper to submit here an outline of its operations.

The section consisted of three independent bases, of two observation posts each, with telephonic communication with a Central used for plotting and calculation. About the first of November, 1918, the positions of the observation posts had been determined—that is, their coördinates computed from observations on triangulation stations. The bases varied in length between 4,000 and 5,500 meters.

The organization consisted of a captain in command and three first lieutenants as chiefs of bases. At each observation post there were four observers and one telephone man; and at each base computing and plotting room at Central there were two computers; and, in addition, there were ten chauffeurs and eight telephone operators.

The section was equipped with the French telemetric type of instrument, and there was a horizontal and vertical observing instrument in each of the six observation posts. These were installed in specially designed portable houses, on rigid tables resting on separate foundations from the floors of the houses. The houses were camouflaged with the common burlap covered chicken wire.

The front covered for ranging operations was about 25 kilometers. Approximately half of this distance could be observed

from two separate bases, and with good visibility it would have been possible to adjust for ranges as great as 25 kilometers.

It should be understood that these telemetric sections are used exclusively for ranging, and that they are not intended to do duty in any other field of observation. It is therefore their aim to carry out the greatest amount of detail relative to the accuracy of locations, observations and adjustments.

One of the principal difficulties encountered by this section at the front was the lack of proper equipment and data, by the Artillery, necessary for the ranging on high bursts. In particular, prolongation abaques for each type of shell, variation of powder charge and size of gun are required, and comparatively few batteries possessed these charts. Also, there were two types of time fuses available for premature bursts—the so-called ''L. D.'' fuse, with a maximum time interval of 52 seconds, and the ''L. D. A.'' fuse with a maximum of 70 seconds. The two types were suitable for shells of all sizes, except the 75 mm. field piece and certain naval guns operating along this section of the front. Only comparatively few batteries were, however, equipped with these fuses.

Owing to the lateness of arrival of this ranging section at the front, there resulted only three attempts at ranging and in none of these instances was any adjustment obtained. This was due twice to poor visibility and once to the failure of the fuses to function. The first attempt was made during daytime, and was for an American battery of 19 G. guns. Two bases were employed and the gun-target range was about 11,000 meters, From the point of fictitious burst the posts from one base were distant about 19,000 and 23,000 meters; and from the other base about 16,000 and 19,000 meters. Three shots were fired, but no bursts were observed, and the indications were that this was due alone to the poor visibility that existed.

The second attempt was made at night for the same battery, ranging for the same target. The fuse was constantly shortened during the firing, but no bursts were ever seen. The battery commander, however, had stationed observers on hills just overlooking the battery, and these reported that the shells did burst high in the air. It seemed, therefore, on account of the poor visibility encountered that the telemetric stations were too far distant from the target, being in this case about 10 kilometers in rear of the battery.

The third attempt for adjustment was for a French battery of

164 mm. naval guns. Four shots were fired, but no bursts were observed, and the French S. R. O. T. Stations reported that the shots were percussion bursts, showing, of course, that the fuses did not function and that adjustment was therefore impossible.

Plans were just being made to move the section farther forward, but the rapid development of the Armistice made such plans useless. Although no data was obtainable as to the accuracy of this method of ranging, the experiment did afford an opportunity of studying the problems involved concerning the operation of such sections under conditions encountered at the front. From previous observations, however, in connection with the French and American Artillery, from similar stations along the French front, it was considered that the system worked well and was worthy of maintaining. Further experimentation will, in all probability, be made with it, but reference to this is made in this report under the caption of "Suggestions."

The foregoing comment on the telemetric sections has been outlined principally because it is considered that those sections afford the best opportunity available for any study and development of any particular method of high-burst ranging, and so, too, in the descriptions of the various methods that are given under the caption of "Systems," more detailed comment is, for the same reason, given to that theory.

II. SYSTEMS.

There were three distinct systems developed by the allied forces; the *Systeme Telemetrique,* formulated and used by the French, and later adopted and used by the Heavy Artillery; the False Angle of Site method, developed and used by the British, and, also, used to some little extent by the American Flash Sections; and the tangent Reticule method which seems to have been studied by the three armies, but which does not appear to have been used at the front to much advantage, and it seems now to have been abandoned. There have also been suggested several variations of ranging on the true trajectory, one of which was employed to some little extent by the Flash sections. The theory of all of these methods presupposes a good topographical map of the ranging area, and available coördinates of gun, target and observation posts.

Most of these systems were fairly familiar to the units engaged in ranging operations, but the French system was little known

outside of its own personnel and the American ranging sections of the Heavy Artillery, so that it is deemed proper to give an outline of it here.

Telemetric System.

One base only, two observation stations, is employed in the adjustment of a burst, though in actual practice it is most desirable that two or even three bases be employed for a check. The bases are connected by telephone to a common ''Central,'' where all of the plotting and computations are carried out.

It is most important in this system, as indeed in all others, that a good determination be made of the observation posts, for, naturally, on the accuracy of these locations depends to a great extent the value of the range adjustments. At the same time, of course, the value of the results depends just as much on the accuracy of the locations of both the gun and the target. This latter data, however, is furnished by the battery commander, and the ranging section is not responsible for it. Orientation is, though, a most important adjunct to all ranging work, and its importance can not be too much emphasized.

The theory of the telemetric system is based fundamentally on analytic geometry. An investigation of the terrain is first made in order to determine the height at which it is desired that the shell shall burst, for it is obvious that the nearer to the target the premature burst takes place the less source of error there will be in the determination of the point of impact of the trajectory. This height, however, has often to be comparatively great so that no mask may screen the burst from any of the observation posts. A fictitious point of burst is therefore determined; and its position, and the prolongation of the trajectory through it, is calculated. Data is then furnished the battery commander enabling him to set the time fuse so as to function as near as possible to the predetermined point. Usually, the gisement and elevation are set off by the gunners in the same manner as though a direct hit by percussion fuse were the object. Other methods, though, may be employed and the adjustment carried out on a ''witness'' target.

In each observation post there are horizontal and vertical observing instruments. These are the same in design, except that the graticules in the eye-pieces are divided each for its special purpose. In this connection, it might be mentioned here that a combined vertical and horizontal graticule has been suggested by Major W.

D. Young, Engineers, Office of the Chief of Engineers. The idea is to graduate the graticule into twelve radical lines, representing the hour spacing of a clock dial, and by means of four concentric circles to "spot" the burst relative to these divisions; and to refer the position "spotted" to a conversion chart.

In determining the height of the fictitious point of burst it is necessary to know the elevation of the gun, target, and of each observing post, and allowance is figured for both curvature and refraction. These elevations are usually determined from the map contours.

The computed gisement and vertical angle to the fictitious point of burst are set off on the instruments, and the observers do not shift in any way this pointing during an adjustment, but "spot" the actual burst on the divisions of the graticules. In order to facilitate and check the values a great part of the data required is both plotted and computed, and these two operations are carried out separately at adjoining tables. The greater portion of both the plotting and computations concerns the data required for the fictitious point of burst, and after such data is once obtained the determination of the adjustment is very much simplified, in many of the operations by means of graphic scales; and with well trained plotters and computers the initial data for an adjustment is supposed to be submitted within half an hour; after the observations are made the results are supposed to be submitted within five minutes.

The theory of the telemetric system is based fundamentally on analytic geometry, and the deviations of all shots are figured relative to the trajectory through the fictitious point of burst, which trajectory is computed to pass through the estimated position of the target. The deviations between the computed and actual points of burst, both horizontal and vertical, are determined by the method of "sensitiveness" both lateral and longitudinal. The lateral sensitiveness is the lateral displacement of the actual burst with respect to the point of fictitious burst, as measured in angular deviation along a line perpendicular to the line connecting the right hand observation post with the fictitious point of burst. In other words, the lateral sensitiveness, or displacement, is simply the angle of deviation from some predetermined point of reference of known distance from the right hand telemetric station. The distance multiplied by the sine of one centigrade is the unit of measurement.

In a similar way the longitudinal sensitiveness is measured from the left hand telemetric station, and it is the displacement of the actual burst as it varies in parallax, with respect to the fictitious point of burst, measured along a line connecting the right hand telemetric station with the fictitious point of burst.

It is considered that the rather involved theory and formulæ embraced in this system would require too much detailed explanation to be incorporated in its entirety in this report, especially as the translations of the French manuals are available, and therefore only a general outline will be attempted.

The basis of all telemetric angles is a directing line, which, in turn, is a perpendicular to the base line drawn at each telemetric station. The directions are expressed in counter gisements, and are measured counter-clockwise from the Lambert north.

Abaques are furnished for each caliber of gun, type and initial velocity of shell, variation of powder charge, fuse, etc., from which the prolongation of the trajectory for any particular height of burst can be scaled.

The important elements of drift and lateral deviation due to wind are both allowed for in the adjustment; and, so too, is the correction for inclination of the trunnions determined.

As has been mentioned, two instruments are used in each observation post, one for horizontal angles and one for vertical angles. They are, in general, of the same design, except that each graticule is graduated for its special purpose; and the horizontal instrument has an extra telescopic attachment for accurately setting off the counter-gisement. The general appearance of the instruments is similar to that of the transit, with standards of extra strong construction to carry the heavy telescope. This telescope is of the well known *Campagne Type X. Longue-Vue Monoculaire a' Prismes* style, fitted with three different powers of lenses. The graticule divisions in both instruments cover 200 centigrades, with the line of sight through the 100 centigrade mark. The plates are just the reverse of the transit, and are graduated into even grades. For setting the direction instrument only the nearest grad is set off on the lower plate and the burst is read, in centigrade on the subscale in the eye-piece.

Both instruments, in each station, are mounted, instead of on tripods, on stable specially designed tables. Very refined means are employed for orientation, and it is the general practice to try to locate the two observation posts so that sights can be taken

from one to the other. It is, though, the general impression among American observers who have examined the instruments that considerable improvement could be made as regards both the accuracy and simplification of the adjustments. It would seem desirable that they be designed along lines more closely resembling the transit, and, too, that the general principles of transit surveying be employed in the observations.

With the use of only two telemetric stations, comprising one base, there is no check at all on the accuracy of the observations—except in the employment of another base, whereas, if another station were used—three observation posts, comprising two bases—the adjustment could be checked in a most satisfactory manner. The French method, though, of turning off the angles from a directing line would have to be changed, and the angles read by gisement.

False Angle of Site Method.

There are two general methods of ranging by the False Angle of Site; one, ranging on a point on a different trajectory, vertically above the target; and, the other, ranging on the true trajectory. The observation principles of both are the same, in that the purpose is to ''spot'' the burst, both horizontally and vertically, by means of suitable instruments in accurately located observation posts. The general system of determining a fictitious point of burst, and directing the instruments to this field of view, is employed, though in neither of the methods is the refinement of detail carried out to the same extent as that prescribed in the Telemetric System.

The first of these methods—ranging on a point vertically above the target—was adopted by the British Artillery. In preparing the initial data the correct Tangent Elevation is used, and the fuse is set to give a burst at the target. An Angle of Site, though, is used much greater than that for percussion fire, so that the shell will burst in air on a trajectory different from the correct one that will pass through the target. This false angle of site is determined from the study of the terrain and the topographic data at hand, with the purpose of causing the burst to be seen from the observation posts. Should, however, the bursts not be in the field of view, the fuse is shortened or lengthened until the proper results are obtained—the object being that the burst shall be near a point vertically above the target. After the bursts are observed and plotted, the M. P. B. (Mean Point of Burst) is plotted on the usual

form of plotting board and its position submitted to the battery commander. This data embraces the angle of site to the M. P. B. and the variations for range and line. With this information at hand the correct adjustment can be figured. Since the trajectory ranged on is not the same as that passing through the target, a correction is made for "NON-RIGIDITY": this correction is gotten from the range tables by interpolating between the angle of site for the target and the observed angle of site for the particular tangent elevation used for the burst. The burst does not, of course, take place on a vertical directly above the target, so that a correction for range must also be made to give the correct Tangent Elevation.

A certain amount of drift must also be allowed for in the prolongation of the trajectory from the point of burst to the target, but this is usually of a negligible amount, up to angles of sight of 4 degrees, except at very long ranges when the shell is very near the envelope. Tables are used for obtaining this correction for the angle of site. Other corrections for atmospheric pressure and cross wind component are provided for in tables furnished the battery commander.

In the second method—ranging on the true trajectory—the initial firing data is the same as that intended for percussion fire on the target, except that the fuse length is shortened in order to give a burst in air that can be seen from the observation posts. By means of a vertical trajectory graph, with a known angle of descent, the height and distance of the burst from the target can be determined, so that observing instruments can be pointed in the direction of the field of burst. Corrections for wind drift and other influences are made in much the same manner as is employed with the False Angle of Site. In general the principle is much the same for that of the Telemetric System, but with much less refinement of detail.

Tangent Reticule Method.

The Tangent Reticule method is simply a variation in form of ranging on the true trajectory, with the addition of a reticule in the eye-piece of the observing instruments that can be adjusted so that the divisions on the reticule will be nearly parallel to the slope of the trajectory in the vicinity of the burst.

Bursts that are very nearly on the same trajectory, and near the same altitude, will then be observed on the same division line in the

reticule, tangent to the trajectory. Quite an amount of detail is involved in determining the adjustment, but most of it is obtained from charts and graphs. These embrace the Residual Coefficient—the correction to the angle of elevation in order that the trajectory through a determined fictitious point of burst may be adjusted to pass through the same point under different firing conditions; the determination in range for the horizontal projection of the burst on the horizontal plane of the target; the angles and distances from each observation post to the fictitious point of burst; the vertical angles to the fictitious point of burst; the elevation coefficients—ratio of angles of site to angle of fall; and the inclination of the micrometer eye-piece.

It seems, though, to be the rather general impression that the Tangent Reticule method is inferior to the Telemetric System, and, in the case of ranging for the smaller caliber field guns that the False Angle of Site Method would give satisfactory results without necessitating the same amount of refinement of adjustments.

III. INSTRUMENTS AND OPERATIONS.

Reference has already been made to the two types of instruments used in ranging—the "Type X" used in the Flash sections, and the specially designed instrument used in the Telemetric sections. The latter was, decidedly, the best style of instrument, though it was suitable only for ranging and was not adapted for general observation purposes. It possessed many points of merit and it is felt that it might well be used as a basis to design a more suitable instrument which might be generally used for observation purposes, and, with extra attachments, be employed for high-burst ranging. It would, too, be very desirable if one instrument could be made to satisfy these requirements, and, also, to be of sufficient accuracy for determining the position and orientation of observation stations. This latter requirement might, however, be hard to fulfill, so that observing and ranging sections should also be provided with transit, alidade and plane table.

Both types of instruments, observing and ranging, are far from satisfying the requirements for such purposes, and it is felt that there is a large field for improvement. Many desiderata must be taken into consideration in formulating a new type, but these can not be properly considered until definite methods of ranging are adopted. This would apply more especially to the graduations on

the plate, vertical arc and reticule eye-piece. As mentioned before, the telemetric instruments were graduated into grades, while the instruments of the Flash sections were graduated in mils. It would, of course, be most desirable if such instruments were graduated in the same system or that used by the artillery; and indeed, in this as well as in other details there should be the closest liaison between the two branches of service.

Too much emphasis can not be given to the subject of orientation. Observation and ranging sections should be thoroughly trained in the many methods of triangulation and traversing—or, if not all, at least a portion of the personnel should receive special instruction along these lines. In France many new methods were brought to light greatly facilitating such operations, and the field of endeavor is still a very broad one, affording opportunities for improvement concerning both instruments and methods.

In France some of the Sound Ranging Sections developed the principles of locating their stations by means of sound surveys, and although it may not be feasible to train observation and ranging sections along these lines, there are, nevertheless, great possibilities in developing such methods for reconnaissance locations.[1]

The German Flash Sections, and, afterward the British, also made use of the Vertical Light Ray for preliminary locations, and this would also seem to be capable of being developed for quick methods of obtaining a good approximate station location. The method is one of using a vertical light ray, instead of the usual forms of targets, to observe upon, thereby continuing a triangulation net in mobile warfare without necessitating the erection of special targets.

The light ray is contained in a cartridge, fired from a specially designed pistol. The charge lights up on its ascending path, and the deviation from the vertical is so slight as to give a very small error. The best results are obtained in distances between 2 and 8 kilometers. The approximate bearing on which to direct the observing instrument is, of course, known and the observer is supposed to pick up the first shot, intersect the second, and check on the third shot. Conditions in the advance area must, of course, be

[1]The principle employed is that of exploding charges at various points in a triangulation net, and, then, knowing the velocity of sound, to determine accurately the interval elapsed between the time of the explosion and the time of the sound reaching the observer, and from such data computing the distances between stations.

met in the operation of such methods, but it would seem that the scheme should offer a very interesting field for development in connection with reconnaissance surveying for the location of observation and ranging stations.

IV. REPORTS AND MANUALS.

Owing to conditions which existed during the War, the manuals which were prepared on High Burst Ranging were very limited in their treatment of the subject. Indeed, the rather general practice was for each unit interested or engaged in the system to formulate its own details of operation; for, mostly, the manuals at hand did not prescribe very clearly any particular form of procedure. The exception, however, was the French Telemetric System and the British False Angle of Site Method. The manual for the former is precise, and each step in the operation is very thoroughly explained; and, in the latter paper, although the principles are made quite clear the details of some of the steps are rather lacking in clearness. In the "Manual for the Artillery Survey Section" (Observation Groups and Sound Ranging Sections), Translation or Precis made by Maps, G. H. Q., of the *Vorschrift fur Artillerie-Messtrupps*) is given, perhaps, the best general description of the fundamental principles involved, and this seems very likely to have been about the first compiled treatise on the subject.

The following reports and manuals on the subject are now on file in the office of the Chief of Engineers:

"Adjustment of Artillery Fire by Flash and Sound Ranging Sections." Prepared by G-2-C., G. H. Q., A. E. F., August, 1918.

"French Method of Ranging by Means of Bursts in Air," from report by Major Pendleton on French Methods of Ranging Artillery.

"Ranging on a Shrapnel Burst, by Lieutenant Colonel E. M. Jack, General Staff, British Army.

Pamphlet, "Translation French Telemetric System, High Burst Ranging."

Pamphlet, "British False Angle of Site Method, High Burst Ranging."

"Manual for the Artillery Survey Section" (Observation Groups and Sound Ranging Sections), Translation or Precis made by Maps, G. H. Q., of the Vorschrift fur Artillerie-Messtrupps).

"Reglement Provisoire, sur l'Emploi des Sections Telemetriques de la R. G. A. L. pour le Reglage des Tirs por Coups Fusants Hauts." October, 1917.

"Annex 1, an Reglement Provisoire d'Octobre 1917, sur l'Emploi des Sections Telemetriques d'A. L. G. P., pour le Reglage des Tirs por Coups Fusants Hauts." April, 1918.

"A joindre a l'Annexe 1, an Reglement Provisoire d' Octobre 1917 sur l'Emploi des Sections Telemetriques Reglage por Coups Fusants Hauts avec Section Telemetrique. Resultats obtenus a MAILLY en Mai 1918."

There are also a number of smaller and less important pamphlets on file, and these, too, might perhaps prove of use to anyone especially interested in the subject.

It will be noted from the foregoing summary that sufficient data is now at hand to determine a definite plan of experimentation, with the idea of formulating and adopting some one of the several methods now in vogue. Quite a good deal has already been accomplished in the way of an investigation of the theories of the four general systems, so that now it would seem proper to direct efforts in determining the degree of precision, mobility of the sections, and, most especially, an improved observing instrument of a higher order of accuracy—all suitable for the particular system that shall be adopted.

THE BARRIER TYPE OF TANK DEFENSES[1]

In the St. Mihiel and Grande Montagne Sectors by the 304th Engineers, Under Col. James F. Barber.

Report By

Capt. A. C. Rubel,
Topographic Officer.

Tank defenses, employed in such large numbers during the latter stages of the war, consisted of two distinct types: the explosive trap or mine, which of itself was capable of putting a tank out of action; and the barrier or obstacle, which was employed on the principle of delaying the tank in such positions and for a sufficient length of time to enable the artillery, trench mortars, or other agency to destroy it. Both types of defense were dependent largely upon the element of surprise for their effectiveness, the former by clever camouflaging and the latter usually by employment in village streets, roads, and places where aeroplane observation would have difficulty in picking them up. Neither type was often used alone, but usually in such a position that in avoiding one the other would be encountered. (See Plate No. 30 in report "Destruction of Enemy Traps and Mines.")

The following data, illustrations and sketches cover the most common types of the barrier stop that have been encountered by the 304th Engineers in their experiences along the Meuse and in the Argonne during the last three months of the war.

Fig. 1 shows a road barrier erected on the Damvillers-Etain Road near Gibercy. This is a counter-poised gate and fence of rails and I-beams, the purpose being to delay the tank for a sufficient time to allow the artillery to register.

A similar type of barrier was encountered by Sergeant Bremoli, Company F, this Regiment, in the area around Ornes. A cap attached to the pivot communicated with a large Bangalore torpedo under the road. Lifting the gate or displacing the horizontal rail would detonate the mine, and either destroy the tank that caused the displacement or blow a trench in the road, which would prove a serious obstacle.

---

[1]Supplementing Report on Destruction of Enemy Traps and Mines.

The mined type of gate apparently was not common, as out of quite a number observed over the area only one was mined.

Fig. 2 shows another and similar road barrier on the Damvillers-Etain Road near Damvillers. This consists of two heavily reinforced and braced concrete posts, about 10 feet in height. Four heavy steel cables, anchored in one post and secured to the other by hooks to allow passage if required, formed the barrier. The whole stop is strong enough to hold the heaviest tank and cannot be passed unless the cables are let down. Machine guns were counted on to prevent the supporting troops from tampering with the cables, while grenades and anti-tank guns put the tank out of commission.

Fig. 1. Road Barrier near Gibercy.

A somewhat similar type of barrier, consisting of two staggered lines of reinforced concrete pillars across the road, blocked all the roads leading into and out of Montfaucon. They were permanent and did not permit of the use of the road by either friend or foe. (See Fig. 3.)

As an accompaniment to the above types, the barricaded road was either in a heavy cut or fill, so that the tank could not easily pass around it; or if the passage could be easily accomplished, the area on both sides for a distance of 100 yards or more was mined.

Another defensive system involving the use of reinforced concrete pillars and cable was found in the region just east of Verdun, forming a part of the defensive system of Etain. This consisted of

a long stretch of heavily reinforced concrete posts about 2 meters high by $1\frac{1}{2}$ meters square, spaced at intervals of about 15 meters and connected by a very heavy steel cable at a height of about $1\frac{1}{2}$ meters. (Fig. 4.) The sytem was flanked by a fairly heavy growth

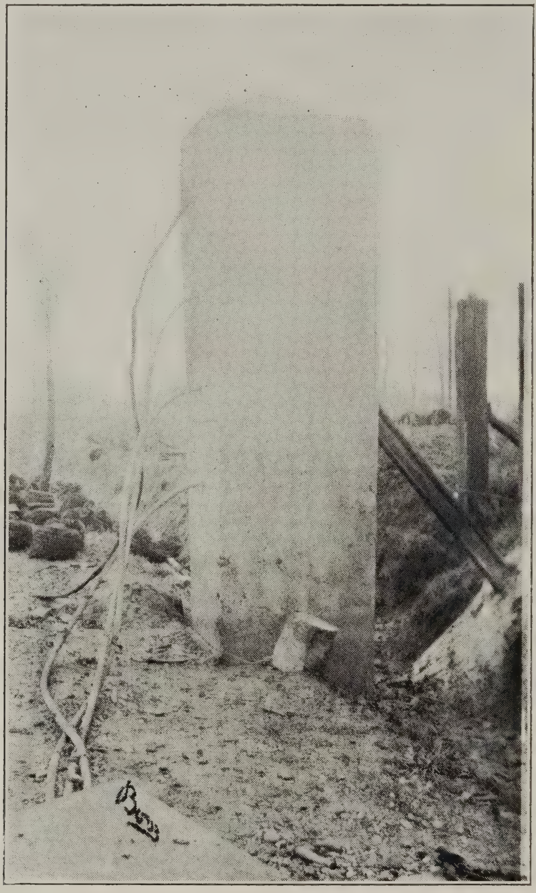


Fig. 2. Road Barrier near Damvillers.

of timber, known as the Bois de Charriere, on one side, and the village of Hautecourt on the other. The purpose of this obstacle was undoubtedly to delay, as no evidence of mines was found. It probably was well enfiladed by artillery from one or both flanks. In the opinion of the writer this does not form a very effective defense, being easily destroyed by demolition of the posts or cutting

of the cable. As is true of other forms of this class of defense, the device represented the expenditure of an enormous amount of time, material and labor.

Fig. 5 shows a form of staggered stone-wall barrier very common in the villages of the Grande Montagne Sector. These are walls from 4 to 6 feet high, so staggered as to either prevent entirely the passage of a tank or to slow it up sufficiently to make it an easy target.

The following extract from comments made by Major Frank W. Hamilton, 2nd Battalion, 304th Engineers, on this subject covers the point very well:

"For entrance to villages a barrier undoubtedly forms the best type of defense. There is, usually, enough of the village left to afford the element of surprise to the tank crews, in that they will

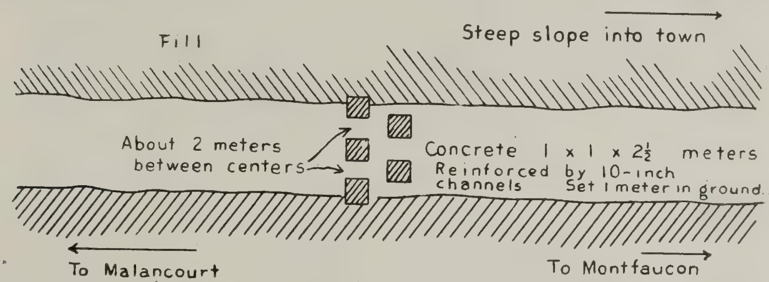


Fig. 3. Concrete Barrier Across Road at Entrance to Montfaucon.

most probably come upon the barrier unawares. Such a situation would be a most difficult one for the tank crews to meet, as they would be in the pocket and at the mercy of one-pounders, hand bombs, etc. Further, an advantage of the barrier type of tank defense in villages is that it is not a constant menace to the garrison, nor is it subject to deterioration from the effects of the weather, as the explosive type would be."

Fig. 6 shows a type of barrier very common in the villages of the old St. Mihiel Salient, the barrier shown being in Vaux-les-Palameix, in the Troyon Sector. This barrier consists of two or more staggered and heavily braced rows of 8 or 10-foot I-beams sunk either in a concrete base or to a depth of about 4 feet in the ground, and standing about 5 feet above. These barriers extended either entirely across the road, blocking all traffic, or were so staggered as to cause a considerable delay in passing through. As in the former types, this barrier was invariably flanked by mines or some other obstacles.

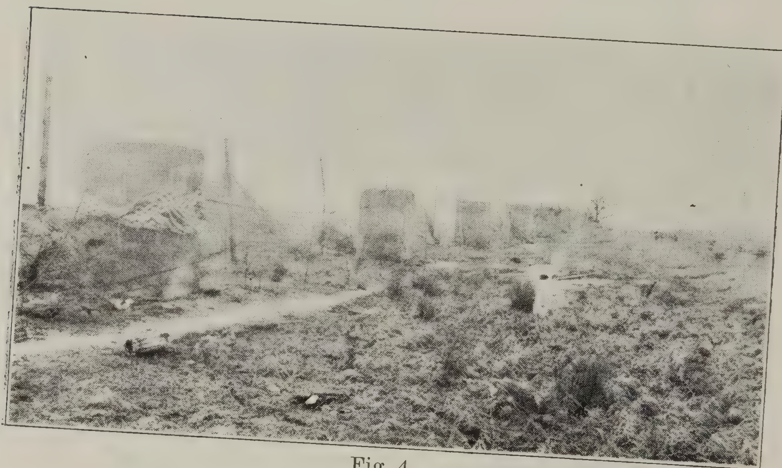


Fig. 4.

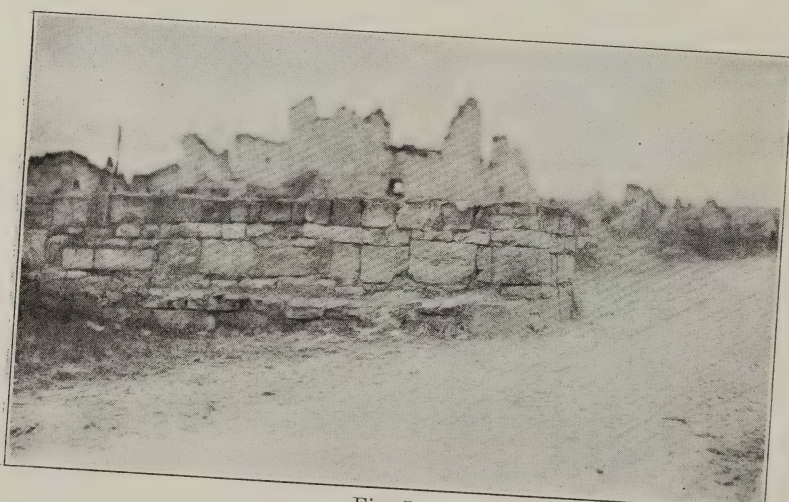


Fig. 5.

Fig. 7 shows what is believed to be one of the older types of tank trap, being merely a large pit about 2½ meters deep, 3 to 4 meters wide, and extending over the path which a tank would be likely to follow. The pit is carefully camouflaged with earth, grass, etc., to represent undisturbed ground. The tank, on attempting to cross such a pit, would crash through and become *hors de combat.*

A number of such devices were encountered in the Troyon Sector, blocking roads and open places through the woods along the Grande Tranchee, which the Germans evidently considered particularly vulnerable to tank attack.

In the level country near the town of Mangiennes, in the Grande

Fig. 6. Barrier of I-Beams in Vaux-les-Palameix.

Montagne Sector, is a very elaborate and extensive system of defenses consisting of two types of trenches. One, illustrated in Fig. 8, consists of a long line of pits separated by a distance of about 1 meter. The pits are dug approximately 5 meters long, 4 meters wide, 3 meters deep at one end and tapering to nothing at the other, the deep end being on the side away from the expected attack. A parapet along the back side of the pits represented a trench, over which the tanks could easily pass. The pits were to be camouflaged with earth in the same manner as described in Fig. 7. The system was partly complete for a distance of 1½ kilometers, and the illustration shows the camouflage being put in place.

Types of tank traps, similar to that shown in Fig. 8, near Man-

Giennes, consisted of a single stretch of trench, without traverse, extending between two thickly wooded areas, perhaps a kilometer apart. The trench represented a tremendous amount of work, as it was probably 14 feet across the top and 7 or 8 feet deep at the deepest point. (See Fig. 9.) The trench was of peculiar shape, in that it deepened from nothing on the side from which the tank was expected to make the attack to a maximum depth of 7 or 8 feet on the other side. It was evidently the intention of the Germans that tanks approaching across the field should go into this pocket, from which egress on the farther side would be impossible. No revetting or mines were observed in connection with this trench, but it is

Fig. 7. Pit in Path of Tank.

quite possible that the Germans had not completed their work at the time the armistice was signed, as there was evidence of the task having been in course of construction but a few days.

Why the Germans used such an obstacle in this region the writer and those with whom he has consulted are at a loss to explain, as it is the least effective and the most expensive in time and labor. It would seem that an explosive system would have been the most logical and effective defense for this locality, which is an open country with the maximum visibility and the resulting total lack of surprise when encountered.

Another type of obstacle was noted in the vicinity of Gibercy, consisting of several staggered rows of circular pits 7 to 10 meters in diameter and about 2 meters deep. Just what was the function

of these obstacles is not definitely known; but, as the water level in this locality is very near the surface and the pits are almost full of water, it is supposed that they were intended as an obstacle to tanks, for which purpose they certainly would have proven very effective. These also represented the expenditure of a large amount of time and labor.

One of the most effective means employed by the Germans was the use of the great land-mines blown in the center of a road in such a manner that the entire width of the road and the ground on both sides for a distance of several meters were entirely uprooted. This means usually was taken at a place where the road was flanked

Fig. 8. Line of Pits with Camouflage Partly in Place.

on either side by the steep slopes of a cut or fill, swampy land, or prepared mines or traps. This was beyond doubt the most troublesome type of obstacle met with, for not only did it prove an obstacle during the actual attack, but it proved also a most effective obstacle for all traffic for some time afterward. Concrete posts are easily demolished by explosives, trenches filled or bridged, and mines rendered harmless; but to repair a road with a crater of the approximate dimensions of 90 feet in diameter by 40 feet deep is a task of some magnitude, which usually was accomplished by constructing a detour, resulting in a great loss of time and labor.

The demolition of bridges, of course, forms a very effective means of arresting the progress of tanks as well as any other form

of attack on ground, and this is very often resorted to; in this case, there is no further use of tanks until either the bridge is repaired or rebuilt, or a new crossing is effected.

The felling of trees across the roads by means of rings of T.N.T. was also encountered on several occasions. This caused a delay, but in no case a serious one.

Fig. 11 shows the means adopted by the Germans to form a very formidable obstacle in the region of Maucourt in the Grande Montagne Sector. The ground in this entire district is very low and normally swampy, but has been drained by a system of ditches leading into small streams which in turn drain into the series of lakes in the vicinity of Mangiennes. The Germans dammed these ditches at favorable points, converting large tracks of land into lakes varying in depth from 1 to 6 feet. The roads traversing these

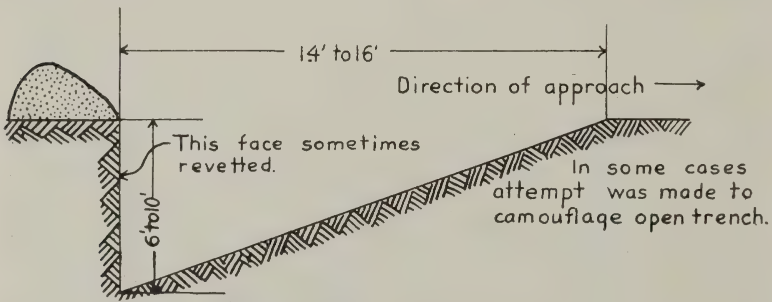


Fig. 9. Cross-Section of Trench Trap for Tank.

areas are built on fairly high fills and were found to be heavily mined in almost every case. It was the evident intention of the Germans, in case of a withdrawal, to blow the roads. The fields being impassable, even for infantry, the roads being strewn with deep mine craters and all points being covered by artillery from the heights beyond, it would have been very difficult to have forced home an attack from that direction.

TACTICAL DISPOSITION OF OBSTACLES.

As stated before, the primary purpose of tank obstacles is to delay, deflect, or destroy; and the means of accomplishing this purpose are as follows:

(1) To stop, delay, or change the direction of a tank's progress in such a manner as to make it non-effective or to cause it to present

Fig. 10.

Fig. 11. Enemy-made Lake near Maucourt.

a favorable target to prepared anti-tank defenses, such as artillery, trench mortars, grenades, etc.;

(2) To deflect its progress into a prepared trap or mine that is capable of either destroying it or putting it out of action;

(3) To deflect its progress into some natural obstacle, such as woods, a river, swamp, or steep slope that is very difficult or im-

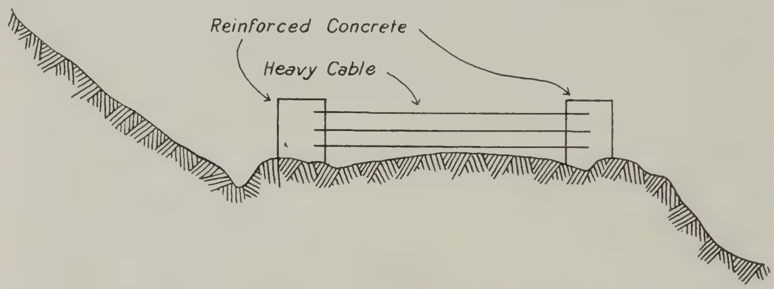


Fig. 12. Obstacle on side of Hill difficult for Tank to pass. Obstacle covered by M. G. and Artillery.

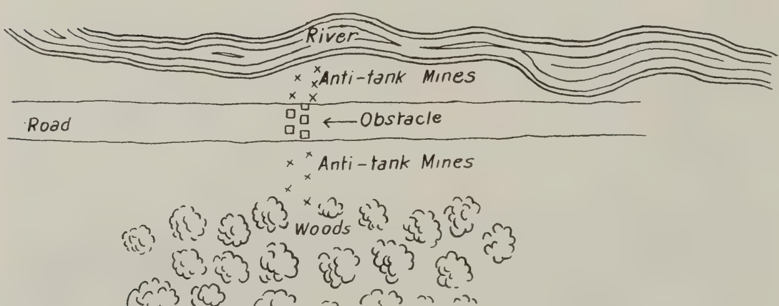


Fig. 13. Obstacle flanked by Mines and Natural Obstacles.

possible to negotiate, or into some obstacle such as a row of buildings, deep ditch, or wall.

The tactical disposition of such defenses demands certain features of the terrain on which to rest, in the same manner that any troop disposition, to be effective, demands some protection of its flanks. The following illustrations represent typical situations encountered by this regiment on the American battle fronts from the Argonne to St. Mihiel. (See Figs. 12 and 13.)

GERMAN MINE FOR WRECKING TANKS.

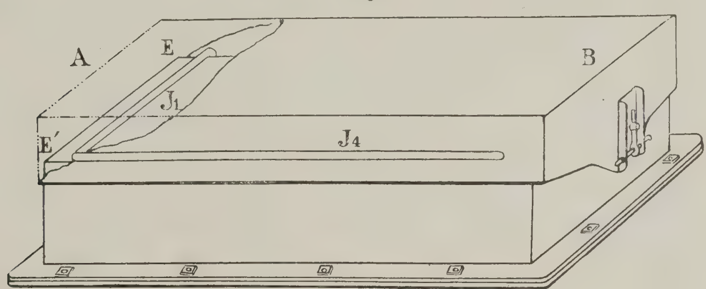
By

Artillery Inspector, Ministry of War[1], French Army.

For some time the Germans have been using a stationary mine of a new model against our tanks. They are scattered over the ground along the probable line of march of the tanks.

A description follows from plans drawn up by the artillery of one of the armies, August 31st, 1918.

($\frac{1}{3}$)



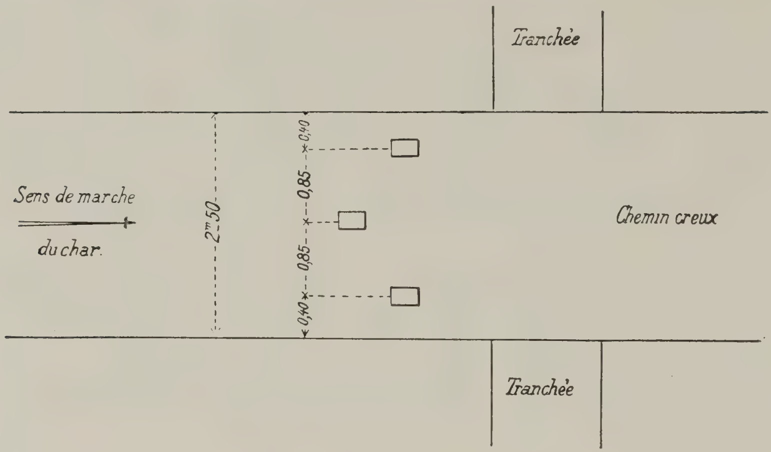
The mine, shown above (see also cross section and plan), consists mainly of a chest of sheet iron EE′FF′, about 25 cm. long, 14 wide and 7 high. The bottom extends slightly, as shown on the sketch.

It weighs 4,900 kilograms in all, 1,600 being an explosive, Perdit type, in eight 200-gram packages.

This charge is primed by two detonators, each of which has a traction-firing device which operates when the pins HH′, drawn downward, free the firing pins P[2].

[1]Forwarded by Military Intelligence Division, U. S. Army.

[2]This arrangement, the system of operation of which is clearly seen by the cross section shown, seems to be very similar to that described in report No. 62 of June 1st, 1917, on the elongated petard used to destroy wire entanglements.



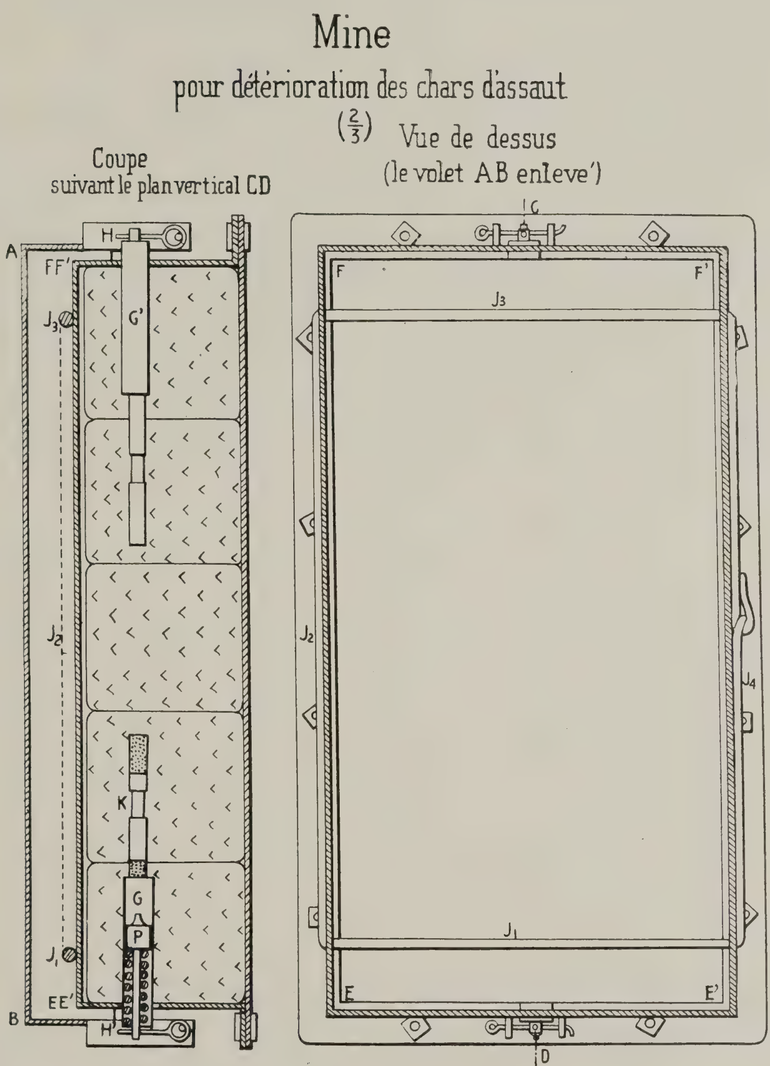
These pins (HH′) are firmly attached to *a cover AB* which is held above the box, EF, by a frame of heavy wire, $J_1J_2J_3J_4$.

When a very heavy weight bears down on the cover, the wires J_1 and J_3 give way and the wall AB is pushed down till it meets EF, dragging down the pins HH′ which release the firing pins.

The device does not operate instantaneously, as a train, K produces a delay of from 2 to 3 seconds.

The mines are buried so that the cover AB is slightly above the ground.

The above illustration shows a possible arrangement for placing mines on terrain where tanks will probably pass.



Mine for Wrecking Tanks.

Vertical Cross Section, CD. View from above (the cover AB removed).

YPERITE MINE.[1]

Quite a large number of Yperite mines[2] intended for the destruction of cellars and shelters, were found in the territory abandoned by the enemy.

These mines (see Fig. 1) are formed in an entirely primitive fashion of *two bottles* wrapped in corrugated paper and connected with a *stick bomb* (*grenade a manche*) by wire bindings.

These bottles, which are of thick glass, have a capacity of 500 $cm.^3$ each and are filled with yperite; they are simply stopped with cork, to which a metal cap surrounding the neck is sealed.

The stick bomb is of the known type with friction primer firing system, the striker of which is operated by means of a cord coming out of the bottom of the handle and which serves as lanyard— . . .

It is reproduced in Fig. 2 as a reminder.

The bomb used for this mine differs from the current model in the few following points:

(a) The length of delay (time passing between the functioning of the quickmatch and the burst of the bomb) is longer (20 seconds instead of 5½).

(b) The handle is shorter (10 cm., instead of 22), so that it will not extend beyond the neck of the bottles; it is painted red.

(c) The charge is composed of 220 g. of explosive of the Perdit type, composed of:

	Per cent.
Nitrate of ammonia	72.0
Perchlorate of potassium	12.7
Tolite	11.5
Sawdust	3.5

instead of 270 g. of Donarite.

[1]According to Report of the Municipal Laboratory of the City of Paris. Forwarded by Military Intelligence Department, U. S. Army.

[2]Sulphide of dychlorethyl BB'.—S $\left\{ \begin{matrix} CH^2\,CH^2\,CL \\ CH^2\,CH^2\,CL \end{matrix} \right\}$ Colorless liquid with slight odor of garlic or mustard.

Forms the active part of the charge of mustard shells (yellow cross).

Is generally mixed with 15 to 20 per cent of tetrachloride of carbon or of chlorobenzine, with a view to increasing the volatility.

Poisonous, causes serious conjuntivitis and, upon touching the skin, produces erythema and then blisters.

The entire engine weighs 3400 g., 1340 per bottle, full (without packing) and 560 per the bomb.

Each bottle contains about 515 g. of the following mixture:

	Per cent.
Sulphide of dichlorethyl	60
Chlorobenzine	33
Tails (110°/15 mm.)	7

the density of which is 1,218 to 15°.

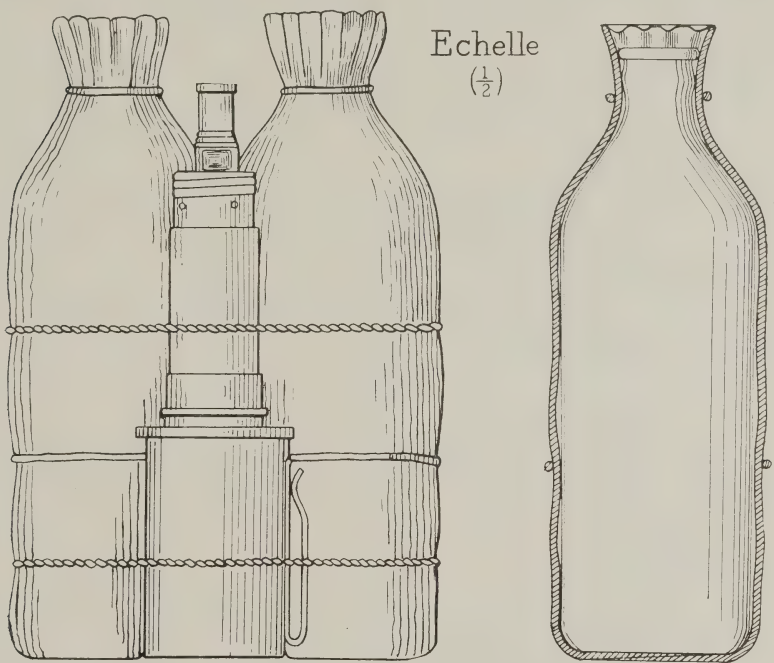


Fig. 1.

These contents are, therefore, formed of an yperite which is very rich in chlorobenzine; in dissolving, this large quantity is intended, in all probability, to increase the volatility of the sulphide of dichlorethyl, as the pulverization realized by the explosion of the cartridge is rather coarse.

To transport these mines the chest used for 75 mm. Gasminen (Yellow Cross), into which they placed, two to a chest, and well wedged, are employed.

A notice, the translation of which follows, is placed in each chest.

Directions for use. Each case contains two apparatuses. One is sufficient to yperite a shelter containing 10 men.

In front of the shelter—

Tear off the label and then bring it back.

Open the wooden chest, then the tin one, tearing off the buckles.

Take out the apparatus, holding it by the handle of the bomb; carry it into the shelter.

Attention—Do not let it fall. Prime the bomb.

In the shelter—

Unscrew the closing cap of the bomb.

Set the apparatus on the ground in the middle of the shelter, the bomb up.

Pull the lanyard of the bomb. *The time of combustion is 20 seconds. Leave the shelter quickly.*

In trenches—

Wait until the detonation takes place, then leave the neighborhood of the shelter quickly.

In case of failure—

Wait in the trench 5 minutes, then place a second apparatus beside the first so that the two bombs touch; then proceed as with the first apparatus.

After detonation—

Do not enter the shelters in which the apparatuses exploded, even with a mask. Otherwise—danger of death.

Avoid the neighborhood of shelters which have been yperited.

Do everything possible to bring back the chest or to collect the chests in the neighborhood of abandoned Minenwerfer.

This *notice* must be brought back and destroyed.

Remark. The apparatuses containing badly stopped or cracked bottles (the dampness of the packing will show this) should not be taken out of the chest. They are to be exploded in the chest by placing another apparatus on the one first opened.

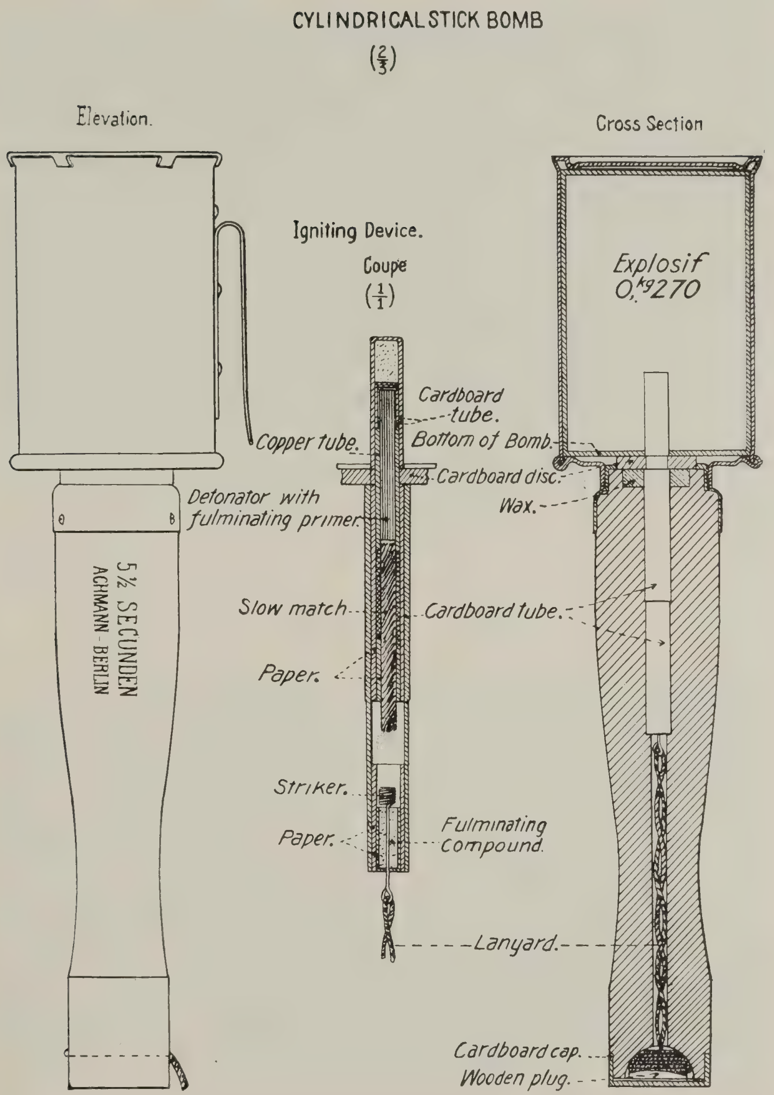

CYLINDRICAL STICK BOMB
(2/3)
Elevation.
5½ SECUNDEN
ACHMANN - BERLIN
Igniting Device.
Coupe
(1/1)
Cross Section
Explosif
0,kg270
Cardboard tube.
Copper tube.
Bottom of Bomb.
Cardboard disc.
Wax.
Detonator with fulminating primer.
Slow match
Cardboard tube.
Paper.
Striker.
Paper.
Fulminating compound.
Lanyard.
Cardboard cap.
Wooden plug.

Fig. 2.

REINFORCED CONCRETE SHELTERS OF GERMAN HINDENBURG LINE.

By

Capt. Aubrey H. Bond,
5th Engineers.

Four distinct types of shelter were found in the area: "Front Line Type," "Support Line Type," "Reserve Line Type," and "Turret Type," with, however, considerable variation in detail and dimensions between specimens of same type. Also, there were found many shelters constructed apparently for special purposes: signal stations, aid station, etc., which could not be classified in any of the four types.

A specimen of each of the four types was measured up and the following sketches made up for the report. There follow, also, such information as was obtainable as to their method of construction and remarks upon their tactical dispositions.

Front Line Type. (See Figs. 1 and 2.)

This type is designed to shelter four men, with comfort reduced to bare necessity. The doors are low and enter directly into the room. The ceiling is so low a man can not stand upright . . .

Note the firing step. Machine guns were fired generally from each end of the firing step. Some ammunition boxes and a pile of cartridges may be noticed at the far end of the dugout parapet, where a machine gun had been operated against the Americans during the attack on this sector the morning of November 10, 1918.

The elevated part on the right is the "Turret"; it consists of a small compartment roofed with a 1-inch armor-plate laid horizontally, and with a circular opening 1 foot in diameter in the center, covered with a heavy sliding door. The turret is, apparently, for observation purposes only.

Support Line Type. (See Figs. 3 and 4.)

The Support Line Type Shelter has two rooms, each accommodating four men, with ample room for bunks, tables and chairs. The arrangement of entrances and hall protects the occupants from

Fig. 1. View of the Entrance to a Combination Front Line, Turret Type Shelter. Camouflage removed.

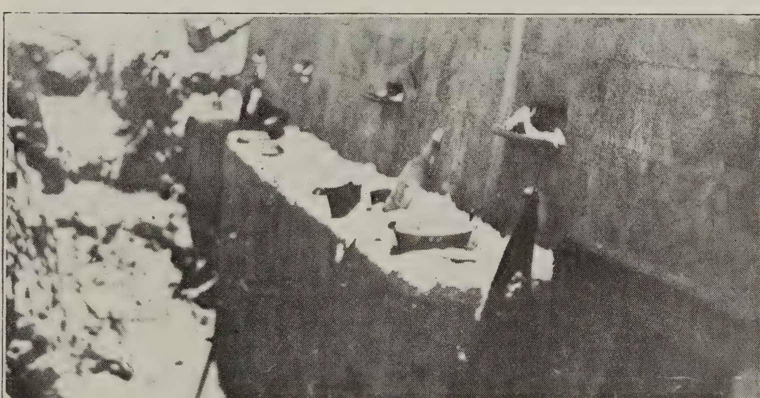


Fig. 2. Closer view of same shelter (snow on ground). The entrances of this shelter are recessed to provide for gas proofing.

direct attack from the outside. Loopholes are provided to command the steps at the entrances. As in the case of the Front Line Type this type is provided with a firing step, and both entrances lead from one open trench with camouflaged cover. This type is sometimes provided with a turret.

Note the conduit for wires, the scaling rungs, and the chimney. The firing step, except at the ends, was apparently utilized chiefly as a shelf. Note the suspended shell case for gas alarm.

Reserve Line Type. (See Figs. 3 and 4.)

This type is characterized by simplicity of design and lighter

Fig. 3. Entrance to support line type shelter.

construction. There is no firing step, though in some cases excavated machine-gun emplacements are found near the entrances. Designed evidently for a general utility shelter, it was widely used in the rear areas and in artillery positions.

Turret Type. (See Fig. 5.)

This type is a more elaborate installation combining the features of observation with those of defence. Note the thick walls, defiladed entrances, and the two turrets of standard type. Bunks for four men in each room were found in most cases. Examples of this class were found in the first stages of construction. Note the heavy floor reinforcing.

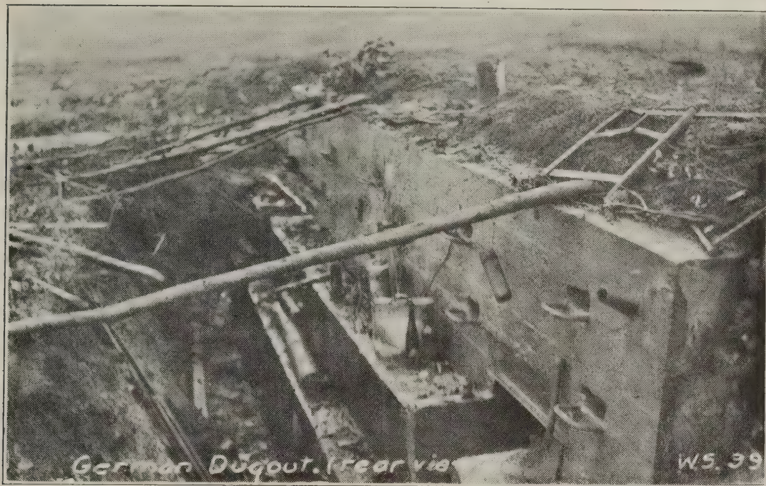


Fig. 4. Same as preceding, with camouflaging removed.

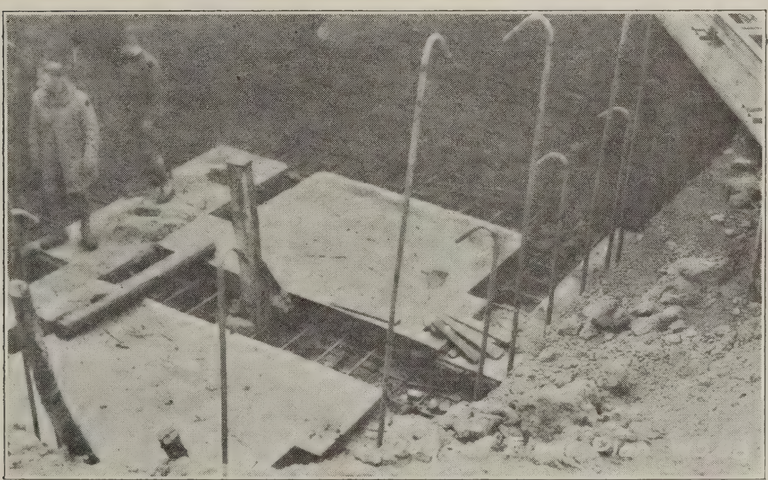


Fig. 5. Floor plan of turret type shelter.

Fig. 6. Excavation ready for footing course.

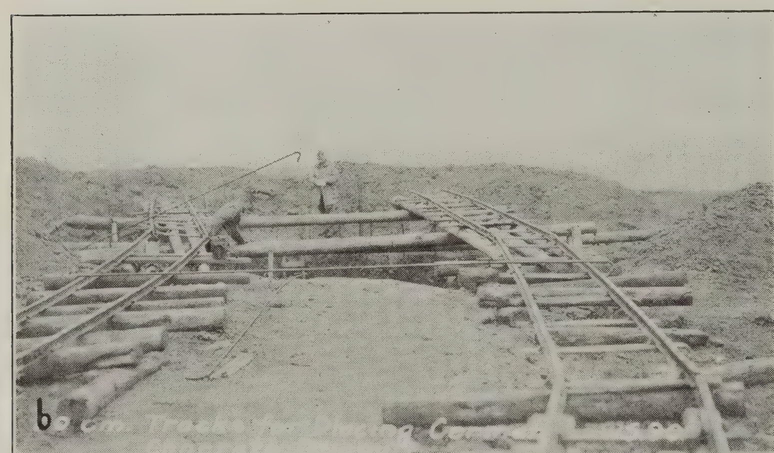


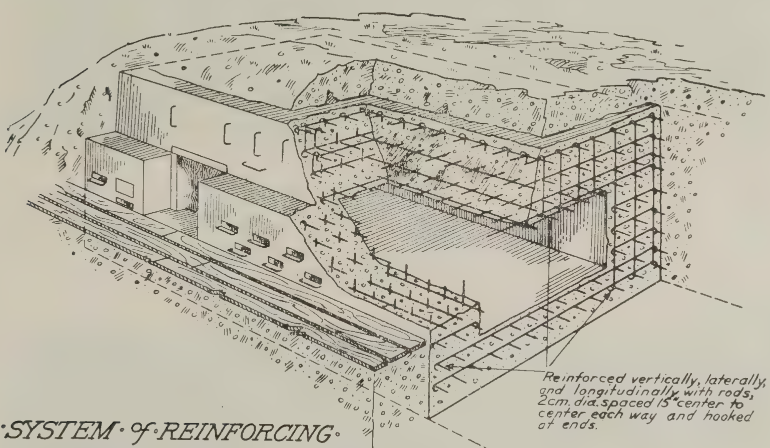
Fig. 7. Showing method of placing concrete.

Method of Construction.

Excavations were made to fit the outside dimensions of the shelters. The walls were cut as nearly vertical as possible and concrete placed against them without exterior forms.

Note the shelf which becomes the trench from which the entrances lead down. The dimensions of this pit are 29 feet wide by 24 feet front to rear by 12 feet deep. It is designed for a Support Line Shelter.

At this stage attention was given to drainage details. Wherever the relief permitted, trenches were excavated in which tile drains



·SYSTEM· of ·REINFORCING·
·GERMAN· CONCRETE· SHELTERS·

were laid with concrete outlets. However, on flat ground, the drainage was collected in sumps and removed by any available means.

The concrete was prepared in central mixing plants from which it was brought up in dump cars on 60 cm. tracks and dumped from the tracks supported by long spars laid across the pit.

Tools for cutting the bars and bending the hooks were found on the site. The system of reinforceing in three directions is shown by sketch and in the following illustrations.

The outside grids of reinforcing were placed, generally, at a depth of about five inches from the surface.

The reinforcing consists principally of ¾-inch (2 cm.) rods, but smaller rods were sometimes used for stirrups. The materials were found to vary in such a way as to suggest that anything available

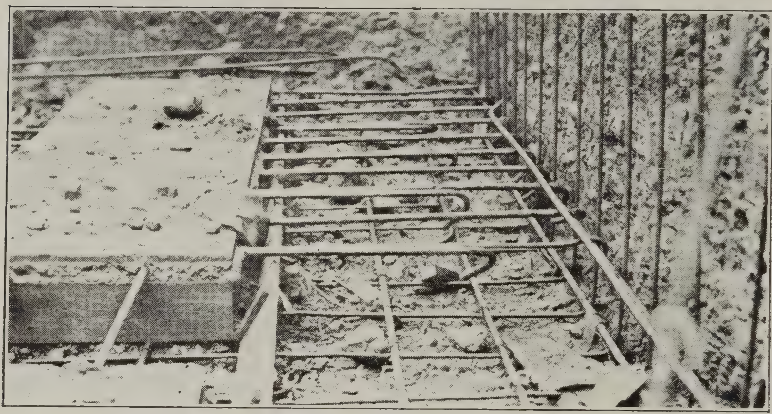


Fig. 8. Floor and wall reinforcing.

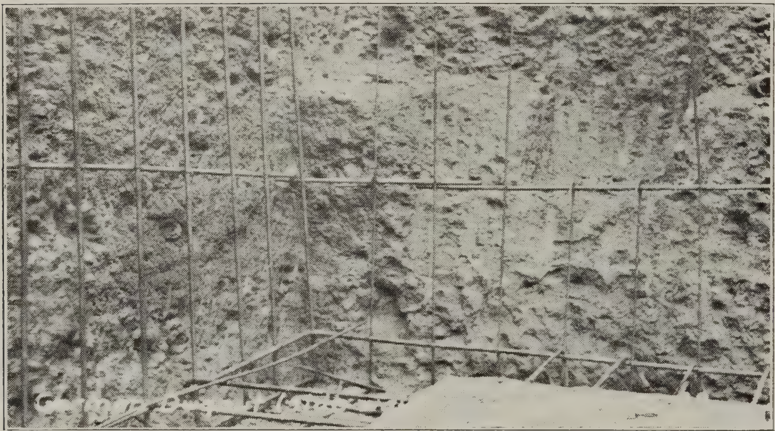


Fig. 9. Wall reinforcing (only partially complete).

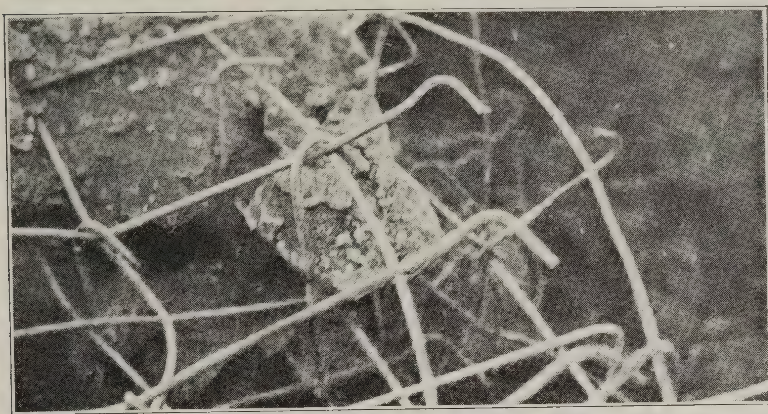


Fig. 10. Roof reinforcing.

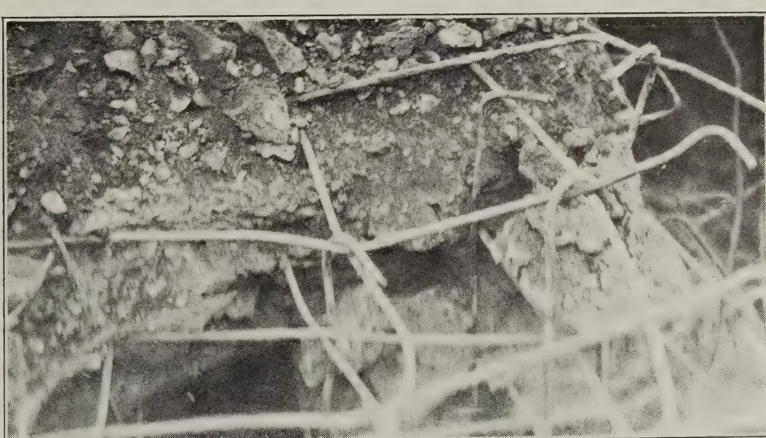


Fig. 11. Roof reinforcing.

was used rather than a certain specified article for each particular place.

The only concrete materials found in the stock piles at the mixing plants were cement and a natural stream aggregate of about equal parts by volume of sand, pea gravel and gravel. From an examination of samples of the concrete it appears that this natural aggregate was mixed up with a rich proportion of cement, making a concrete of fairly good quality.

To complete the shelter, the earth was back-filled to a depth of about 1 foot over the roof, and the remainder spread out and sodded.

Fig. 12. Completed shelter.

The entrances and trench were screened with any available material.

Note the large piles of gravel. The mixers were run by electric motor or steam. Plants were located at intervals of about 2,000 meters along the front.

Tactical Dispositions.

The Front Line Shelters were placed at intervals of about 100 yards along the front and 30 to 50 yards in rear of the front band of wire.

The Support Line Shelters were spaced at approximately the

Fig. 13. Concrete mixing plant in woods.

Fig. 14. Concrete mixing plant.

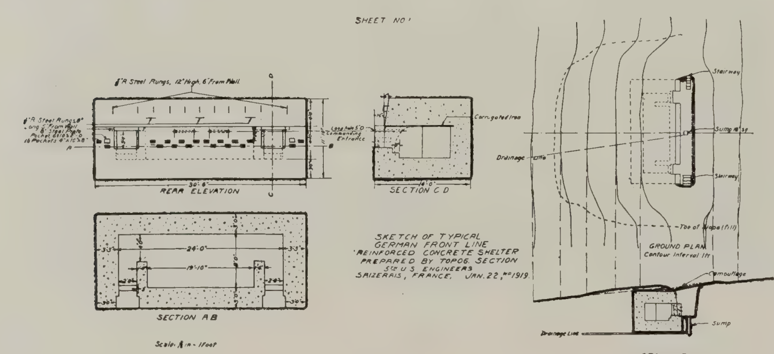
same intervals and occupied a similar position with respect to the second band of wire.

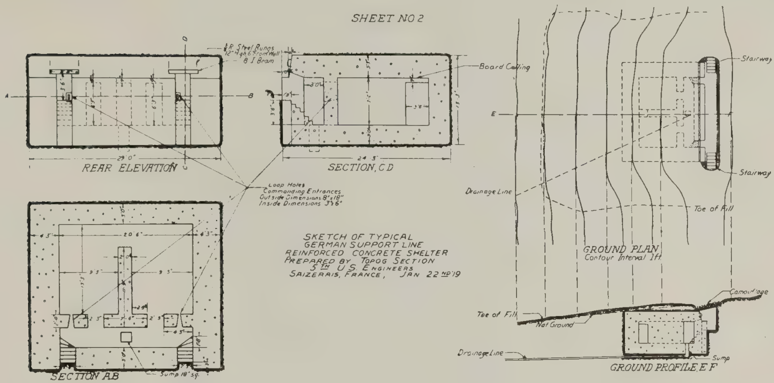
The Reserve Line Shelters were placed at closer intervals, in some places one every 50 yards of front, but echeloned from front to rear in checkerboard fashion over a zone 800 to 2,000 yards deep. The forward shelters of this type were placed about 200 yards in rear of the support line. These shelters were extensively used in artillery positions, and for special purposes in the zone of artillery fire.

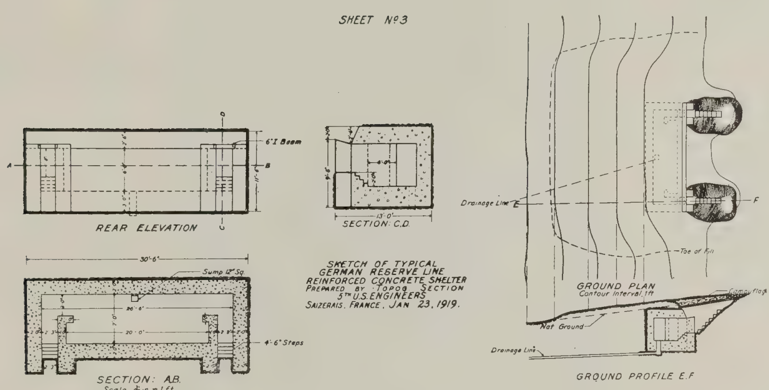
Although "turrets" were found in combination with each of the other types, the typically turret type shelter was found in numbers only along the crest of high ground northwest of Mon Plaisir Fme. They were placed in echelon to a depth of a mile behind the front line.

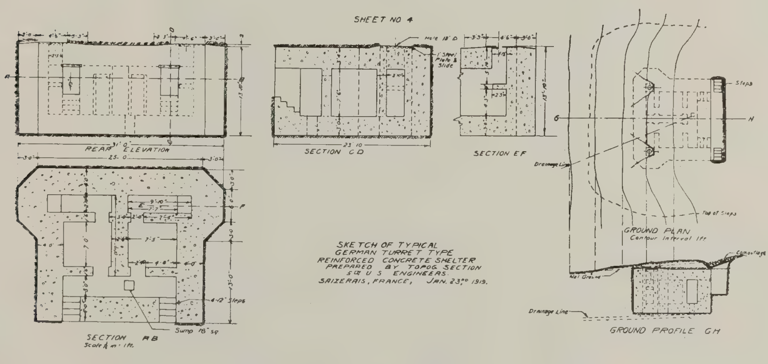
There appeared to be no material difference in arrangement of shelters between woods and open terrain.

The reinforced concrete shelters appear to have suffered little damage from artillery fire. Several cases were noticed where small caliber projectiles had hit the roofs with no damage at all. In one case, a shell of probably 155 mm. caliber had hit a roof with the result that the concrete was slightly shattered but with no noticeable damage inside. In another case, two hits, apparently 155 caliber, side by side, about 6 feet in front of a front line shelter, had shaken the front wall, knocking off the concrete on the inside over a surface of 2 square yards, and exposing the first grid of reinforcing.




SHEET NO 2
REAR ELEVATION
SECTION, C.D
SECTION A.B
Board Ceiling
Loop Holes Commanding Entrances
Sump 18" sq.
Stairway
Drainage Line
Toe of Fill
GROUND PLAN
Contour Interval 1ft
Camouflage
Nat Ground
Sump
GROUND PROFILE, E.F
SKETCH OF TYPICAL GERMAN SUPPORT LINE REINFORCED CONCRETE SHELTER
PREPARED BY TOPOG SECTION 5TH U.S. ENGINEERS
SAIZERAIS, FRANCE, JAN 22ND 19


SHEET Nº 3
6" I Beam
REAR ELEVATION
SECTION: C.D.
Sump 12" Sq.
4-6" Steps
SECTION: AB.
SKETCH OF TYPICAL GERMAN RESERVE LINE REINFORCED CONCRETE SHELTER
PREPARED BY TOPOG SECTION 5TH U.S. ENGINEERS
SAIZERAIS, FRANCE, JAN 23, 1919.
Drainage Line
Toe of Fill
GROUND PLAN
Contour Interval 1ft
Camouflage
Nat Ground
GROUND PROFILE E.F


SHEET NO 4
REAR ELEVATION
SECTION C D
SECTION E F
4-12" Steps
Sump 18" sq
SECTION A B
SKETCH OF TYPICAL GERMAN TURRET TYPE REINFORCED CONCRETE SHELTER
PREPARED BY TOPOG SECTION 5TH U S ENGINEERS.
SAIZERAIS, FRANCE, JAN. 23RD 1919.
Steps
Drainage Line
Toe of Steps
GROUND PLAN
Contour Interval 1ft
Camouflage
Nat Ground
GROUND PROFILE G H

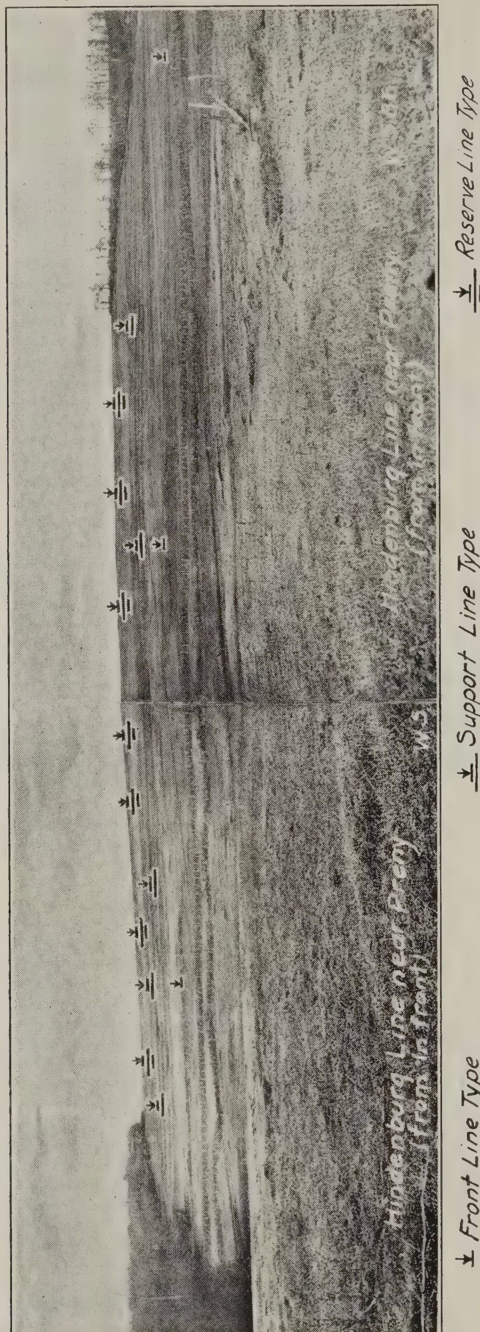


Fig. 15. Arrangement of shelters, Hindenburg Line, near Prêny.

EXPERIMENTS WITH BLAST AND PRESSURE METERS
AND TESTS OF EXPLOSIVES.

By

Col. E. H. Schulz,
Corps of Engineers, U. S. A.

1. *Blast.* The measurement of blast or air pressure of explosives is one of great interest and also of great difficulty. The actual determination involves also the test of powders and explosives for strength and uniformity.

Blast may be defined as the sudden increase or decrease of gaseous pressure either at a uniform rate, or in waves, producing thereby a destructive or shattering effect upon ordinary materials and construction—the result may be due to direct change of pressure, but more probably to the dynamic or hammering force, or to the built-up cushion of pressure.

2. *Devices.* To measure such a blast, several devices have been tried, such as springs attached to pressure discs, aneroid barometers, air compressor and diaphragm meters. One devised about 1904 by the writer, consisted in the compression or expansion of a volume of air, through the medium of a water piston. The instrument was self-registering, and the water used in compressing the air was trapped in a U-shaped tube. Knowing the dimensions of the various parts, the resulting maximum pressure, mean pressure, path and energy in foot-pounds, per square inch, on the surface of the piston could be determined. The instrument is shown on Plates numbered I and II herewith, and was used to measure the blast on the parapets and in the vicinity of seacoast guns. For a description and tests, see confidential mimeograph No. 89, Office, Chief of Engineers, November 10, 1904, on tests of 3″-5″ and 12″ guns. This instrument measured simply the maximum blow, but, as the shattering effect is generally due to the maximum blow, it gave a very close measure of the blast. In normal use, however, it measured only the vertical components of the blast. At long distance and in long sustained waves of large caliber guns or large masses of explosive, the blow is generally uniform in all directions, but in short, sharp blasts, the vertical components are small, and recourse to ells and funnels is necessary. The instrument required several minutes for adjustment after each test.

3. *Diaphragm-method.* The method of breaking diaphragms of various sizes came to the writer's mind several years ago, and has been developed in a machine, or meter, which contains openings of various sizes, leading to pipes or reservoirs of air, either closed or open. The outer openings of reservoirs toward the blast is covered with parchment, paper, or other material. The first meter, Model 1, shown on Plate III, was made at U. S. Engineer Machine Shop, S. W. Pass, La.

The next two meters, Model 2, on Plates IV and V, of slightly different design, were made at Chemical Research Laboratory, American University, D. C., through the courtesy of the officer in command and under authority of Director of Chemical Warfare Service. Two illustrations of this meter are also shown on Plate VI. At this time, the undersigned was in command of Camp Leach, D. C., adjacent to American University, and most of the tests were made with the assistance of Chemical Warfare Service men.

The final tests with the two instruments of Model 2, Plates IV and V, were made at Aberdeen Proving Grounds, Md., with the approval of the Chief of Ordnance. The Patent Bureau of the Ordnance Department is also supervising the securing of a patent for the benefit of the United States. Tests of paper were made at the Bureau of Standards, Washington, D. C., by means of the Mullen Test Machine, which measures the strength by means of glycerine under pressure applied through a rubber of protecting medium, the orifice being $1\frac{1}{8}$ inch diameter or 1 square inch in area. The reading of the Mullen gauge, therefore, is practically pounds per square inch for this size opening ($1\frac{1}{8}$ inch). (See Plate X.)

THEORIES AND FORMULAS OF BREAKING PLATES.

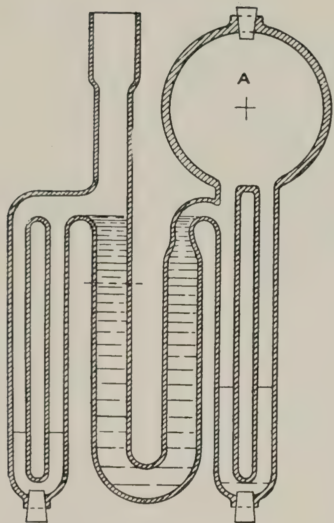
4. The breaking of a fixed plate, etc., may be done under two suppositions:

(a) As a stiff plate, supported and fixed all around;

(b) As a curved or spherical plate, supported and fixed all around.

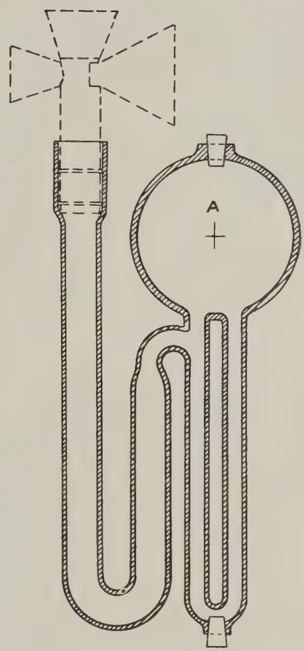
The actual action of a static pressure and also of a dynamic pressure on various diaphragms depends on the stiffness and material and may lie between these two hypotheses, but is believed in the case of thin diaphragms, such as paper, to follow the second supposition. The actual tests have borne this out.

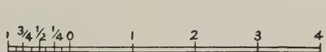
FIG. 1.



Blast is measured by compressing or expanding air in A.

FIG. 2.





SCALE OF INCHES.

Plate I. Diagram of Blast and Pressure Meter.
Compressed Air.

(a) *Fixed flat plates.* Under formula 1, page 313, Kent, we have $\frac{p=3\ ft^2}{2\ r^2}$ for circular plates fixed at edge and uniformly loaded, in which

f=stress in pounds per square inch;
r=radius inches;
t=thickness in inches;
p=pressure in pounds per square inch.

Assuming f and t to remain constant, we see that the unit pressure, or the unit-breaking pressure, varies inversely as square of radius, so that if diameter is doubled, the unit-breaking load is one-quarter though the total load remains the same. Manifestly, a flexible diaphragm without sensible thickness, such as paper, should not be taken as a stiff plate, and therefore this formula would not apply.

(b) Fixed curve or spherical plates.

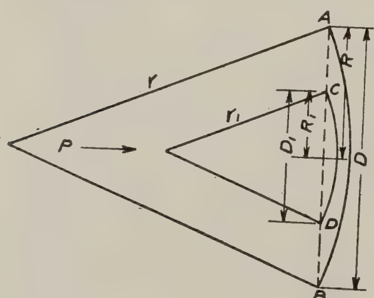
From page 316, Kent, we have—

$\frac{1}{4}\ \pi\ d^2p=\pi\ dts$, where $s=f$ and $d=2\ r$, and r is radius of sphere, or, we have—

$$\frac{\pi}{4}\ 4\ r^2p=\pi\ 2\ rtf,\ \text{or}\ p=\frac{2\ tf}{r}$$

If f and t remain constant, we see that p, the unit pressure or unit-breaking pressure varies inversely as r, the radius of sphere, so that if the diameter of sphere is doubled, the unit-breaking load is halved. In this case the larger the diameter of portion of sphere considered, the larger is the total load.

5. *Action on flexible diaphragm.* The first effect of a uniform pressure on a thin flexible medium, such as paper, is to give it a slight bulge, and however slight this bulge the diaphragm then becomes a part of a sphere and the pressure acts accordingly, as indicated in formula, par. 4b. This is illustrated in the sketch



P=direction of pressure;
Where AB=D or 2R, diameter of diaphragm;
r=radius of bulge or sphere for opening AB;
CD=D, or $2R_1$, diameter of smaller diaphragm;
r_1=radius of bulge for opening CD;

FIG. 7

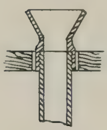


FIG. 3

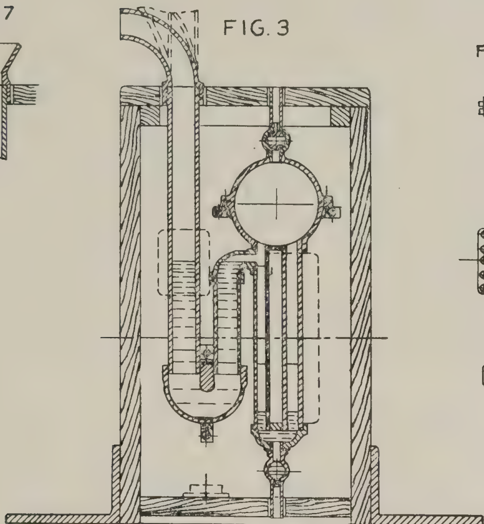


FIG. 6

FIG. 5

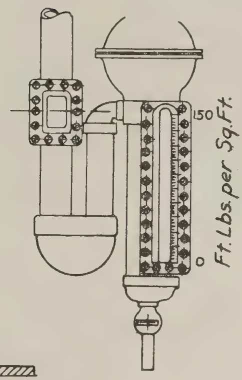
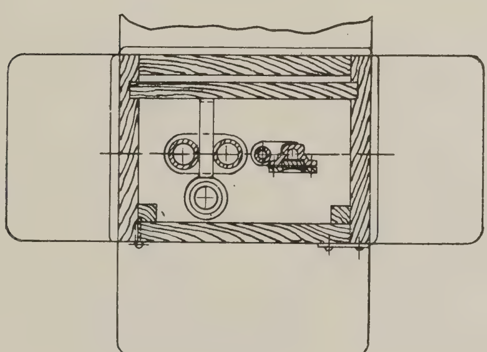


FIG. 4.



SCALE OF INCHES

Plate II. Model of Blast and Pressure Meter.
Compressed Air.

Then, for same pressure and strength of material, $R : r :: R_1 : r_1$. In paragraph 4b preceding, it was shown that the unit-breaking pressure varied inversely as r (radius of sphere or bulge); therefore, this pressure varies also inversely as $D=2R$, the diameter of diaphragm broken. Consequently, if the diameter of rupture is doubled, the unit-breaking load is halved, but the total load on diaphragm is doubled.

It therefore follows, for any given strength of material and any given position and relation with respect to source of a blast, that the unit-breaking pressure acting on a circular opening is inversely proportional to the diameter of diaphragm ruptured.

6. *Theory of the relation of air blast to an equivalent static air pressure.* An air blast or concussion can be measured by the work performed, or by the force of its destruction on some standard material.

While the energy of a moving solid body can not properly be expressed in terms of static pressure, yet in the case of moving gases, involving energy of expansion, I believe, this can be done. This is borne out by the wind formula, $P=.005\ v^2$, where P=pressure per square foot, and v the velocity of wind in miles per hour. With this formula a 100-mile wind gives 50 pounds per square foot of pressure.

The breaking of a diaphragm by gaseous blast is due not only to the direct new pressure due to the theoretic expansion, but also is due to the dynamic effect or velocity of expansion. Therefore, for all purposes, the measure of a blow of air is equivalent to a resultant banked-up pressure at the surface of an obstructing plane, where the observation is to be made. This theory is borne out by observations made, where the resultant shattering pressures were much greater than the mere deduced static pressure for the expansion of the gases of explosion. This resultant pressure, of course, will vary or be modified by the resistance or lack of resistance of the opposing body; if the body is free to move, the pressure developed against its surface will of course be less, depending upon the equilibrium established between the force of blast and the resistance to be overcome.

Therefore the rupture of any diaphragm by gaseous blast is a measure of the destructive blow or resultant pressure at that point, and the smallest opening ruptured will measure not only the force of blast at that point, but will also be a measure of the

FIG. 1

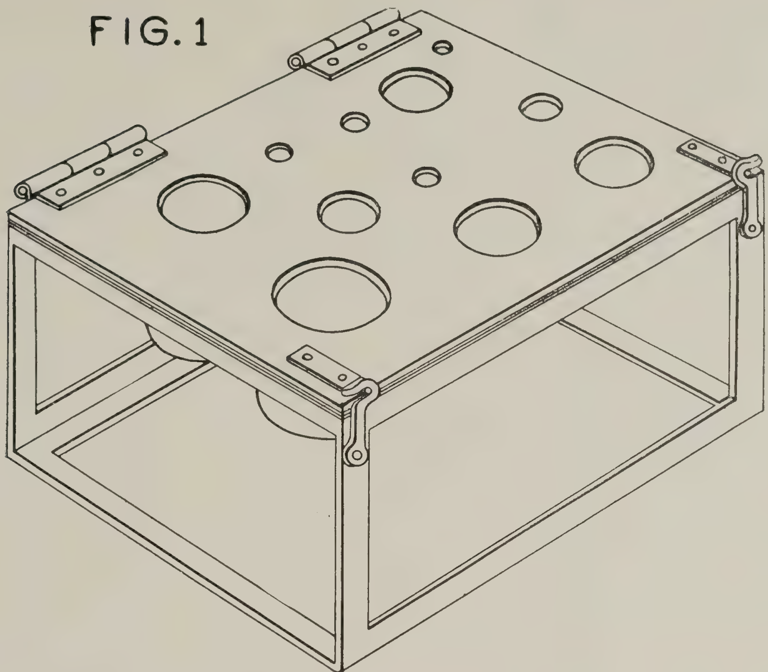


FIG. 2

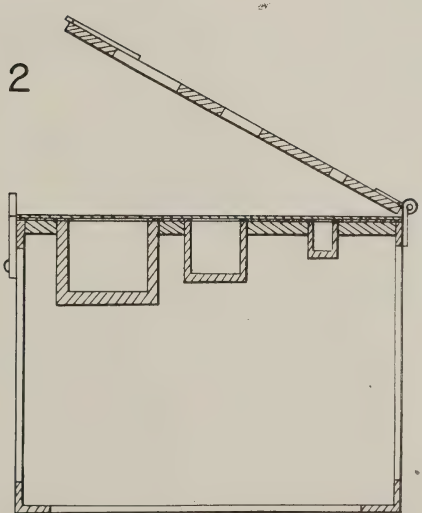


Plate III. Model 1. Diaphragm Blast Meter.

strength of the explosive for shattering effect; in other words, a measure of the speed of combustion or detonation both for the primer and the charge.

7. *Uniform strength of diaphragm material.* Numerous types of paper were tested; all gave fairly good results. Two samples—No. 1, of strength of 14.2 points, and No. 2, of strength 27.5 points—are shown on Plate X. A paper uniformly made and not too strong, say 15 to 20 Mullen points, is the best; but, for light blows and great distance, a 10-point paper should be used, and for heavy blows and short distances a 30-point paper would be more suitable. Most good papers vary from 3 to 10 per cent from their mean strength, so that in a series of tests, using 4 or 5 meters at the same point and same paper, the mean of the readings would give a fair measure of the blast. Frequently, a diaphragm is skipped. This is due to slight slipping of paper, where a heavier grip is needed, or to slight inequalities of strength. However, on the whole, the smallest diaphragm ruptured is a good indication of the strength of the blow. Samples paper No. 1 were generally used. Other good samples which it is proposed to use, and which give even more uniform strengths, are the following:

	Points.		*Sample No.*
No. 1. Onion skin	18.4	(Strathmore)	No. 3
No. 6. Parchment	34.8	(Strathmore)	No. 4
No. 18. Saxon Bond	25.3	(Strathmore)	No. 5
No. 21. Tekao Linen	20.0	(Strathmore)	No. 6
Also, White French	9.8		No. 7

8. *Size and number of diaphragms as actually used.* The model No. 2 has 26 apertures ranging from 2 inches to 1/8 inch diameter, each cup having a depth equal to its diameter. The strength in Mullen points for the 1 1/8-inch opening, based on several tests for paper No. 1, is about 14.2, or 14.2 pounds per square inch. For the other apertures the strengths are determined in accordance with par. 5; that is, the unit pressures vary inversely with the diameter. (See Plate V.)

The table for 14.2-point paper and the various openings is as follows:

Plate X. Types of paper used in Blast Tests.

[This and following samples indicate strength in Mullen Points: Pounds per sq. in. to break circular diaphragm of 1 sq. in., or $1\frac{1}{8}$-in. diameter.]

No. 7. White French=9.8 lbs. per sq. in.

THE LIBRARY
OF THE
UNIVERSITY OF ILLINOIS

No. 1. Plain Pad=14.2 lbs. per sq. in.

No. 2. Certificate Bond=27.5 lbs. per sq. in.

No. 3. Strathmore No. 1 Onion Skin=18.4 lbs. per sq. in.

No. 4. Strathmore Parchment No. 6=34.8 lbs. per sq. in.

No. 5. Strathmore Saxon Bond No. 18=25.3 lbs. per sq. in.

No. 6. Strathmore Tekao Linen No. 21=20 lbs. per sq. in.

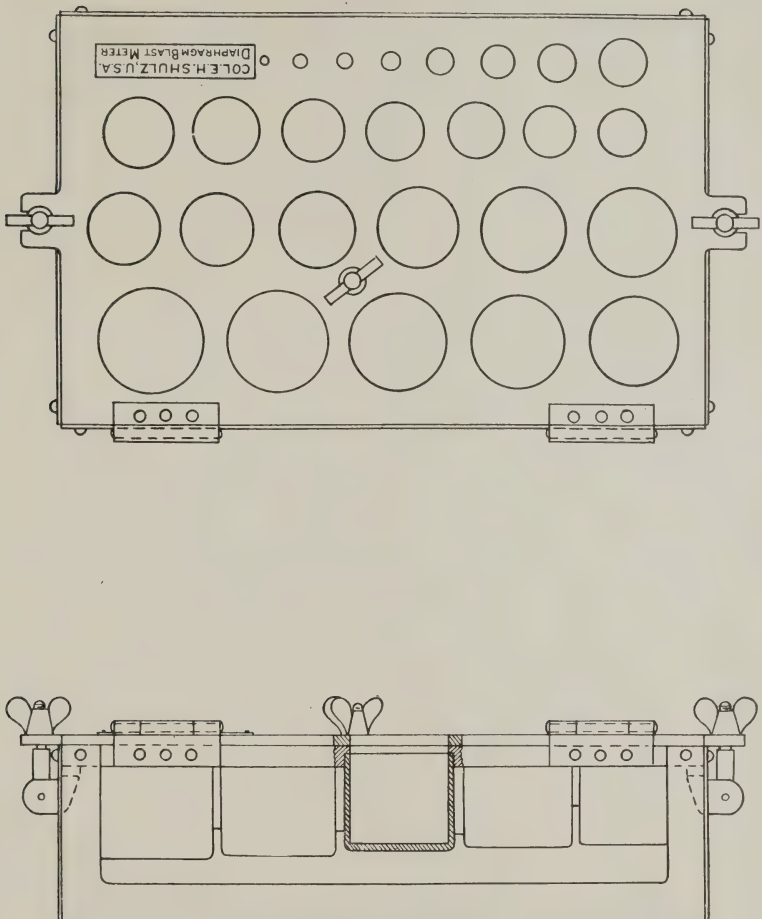


Plate IV. Model 2. Diaphragm Blast Meter.

No.	Diameter.	Strength.	No.	Diameter.	Strength.
	Inches.	*Pounds.*		*Inches.*	*Pounds.*
1	2	8.0	14	1 3/16	13.5
2	1 15/16	8.2	15	1 2/16	14.2[a]
3	1 14/16	8.5	16	1 1/16	15.1
4	1 13/16	8.8	17	1	16.0
5	1 12/16	9.1	18	15/16	17.1
6	1 11/16	9.5	19	14/16	18.3
7	1 10/16	9.9	20	12/16	21.3
8	1 9/16	10.3	21	10/16	25.6
9	1 1/2	10.7	22	1/2	32.0
10	1 7/16	11.1	23	6/16	42.7
11	1 6/16	11.6	24	5/16	51.2
12	1 5/16	12.2	25	4/16	64.0
13	1 4/16	12.8	26	2/16	128.0

[a]Standard diameter.

This paper is .0026-inch thick, or about 400 to 1 inch, and showed a tensile strength per linear inch of 5.4 pounds.

9. *Proposed modification in size and number of diaphragms.* It would appear better to have all openings vary either by definite differences or by definite ratio. The latter method would give more accurate readings in the smaller diameters. A series of 30 holes, varying from 2 inches to .094 inch, the diameter of each 10 per cent less than the next larger one, and strengths based on 14.2 strength of paper, would be as follows:

No.	Diam.	Lbs. per sq. in. strength.	No.	Diam.	Lbs. per sq. in. strength.
	Inches.			*Inches.*	
1	2.00	8.00	16	0.41	38.86
2	1.80	8.89	17	.37	43.17
3	1.62	9.88	18	.33	47.97
4	1.46	10.97	19	.30	53.30
5	1.31	12.19	20	.27	59.22
6	1.18	13.55	21	.243	65.80
7	1.06	15.05	22	.218	73.11
8	0.96	16.73	23	.197	81.24
9	.86	18.58	24	.177	90.26
10	.77	20.65	25	.159	100.29
11	.70	22.94	26	.143	111.43
12	.63	25.49	27	.129	123.82
13	.56	28.33	28	.116	137.58
14	.51	31.47	29	.105	152.86
15	.46	34.97	30	.094	169.85

TABLE.

*Lbs./Sq. In.	No. of Hole.	Diameter.	No. of Hole.	Diameter.	*Lbs./Sq. In.
		Inches.		*Inches.*	
8.0	1	2	14	1 3/16	13.5
8.2	2	1 15/16	15	1 2/16	14.2
8.5	3	1 14/16	16	1 1/16	15.1
8.8	4	1 13/16	17	1	16.0
9.1	5	1 12/16	18	15/16	17.1
9.5	6	1 11/16	19	14/16	18.3
9.9	7	1 10/16	20	12/16	21.3
10.3	8	1 9/16	21	10/16	25.6
10.7	9	1 8/16	22	8/16	32.0
11.1	10	1 7/16	23	6/16	42.7
11.6	11	1 6/16	24	5/16	51.2
12.2	12	1 5/16	25	4/16	64.0
12.8	13	1 4/16	26	2/16	128.0

*Equivalent pressure in pounds per square inch to break a 14.2 point paper. A 14.2 point paper is one of breaking strength against a transverse pressure of 14.2 pounds per square inch when tested with the Mullen machine, on a 1⅛-inch diameter opening having an area of 1 square inch.

NOTE—If a paper of different Mullen strength is used: To get the measure of blow, multiply the pressure obtained from the above table for the smallest opening ruptured, by the ratio $\frac{M}{14.2}$ in which M is strength of paper used in Mullen points, and 14.2 is standard strength for which the table is made.

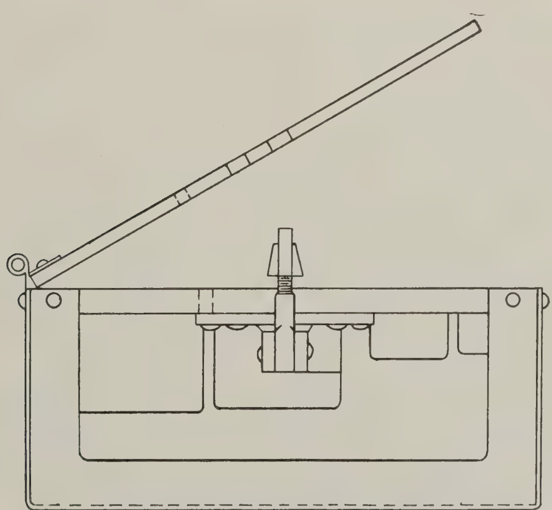


Plate V. End View of Model 2. Diaphragm Blast Meter.

or if two larger holes are added, they would be—

No. 0. Diameter, 2.22 inches; strength, 7.20 pounds;
No. 00. Diameter, 2.47 inches; strength, 6.48 pounds.

In all that follows, the instrument as described in par. 3 and with openings as shown in par. 8 above, was used.

10. *Tests with paper of various strengths.* The above table in par. 8, is for a paper of strength of 14.2 Mullen points. For paper of any other strength, the correct blow or pressure will be determined by multiplying the reading, according to table, by the ratio of paper strengths, $\frac{M}{14.2}$ in which M is the Mullen strength for the particular paper used. For example, if a 20-point paper is used, and smallest rupture is 1 inch, then blow is $\frac{20}{14.2}\times16=22.5$ pounds; if a 30-point paper, and smallest hole ½ inch, then blow or pressure is $\frac{30}{14.2}\times32=45$ pounds per square inch.

Care must be taken not to make tests when there is great humidity, unless frequent Mullen test of the paper is made. This disadvantage can no doubt be overcome by developing a thin metallic sheet or foil of very low uniform strength. Some tests with tinfoil left the metal, where not broken, with a peculiar wavy surface.

11. *Relation of force of blast to smallest size of diaphragm broken.* As shown in par. 5, we may state that if a blow of p unit strength will just break a diameter d, then a blow of $2\,p$ unit strength will break a diaphragm of diameter $\frac{d}{2}$, provided strength of diaphragm remains the same. Consequently, if two different blasts are measured at certain points, we may say that the blasts are inversely proportional to the smallest diameter ruptured, provided distance and relation to source of explosion and strength of diaphragm are the same. Whether the force of two blasts remain in the same relation as the source of explosion is approached, can be determined only by numerous further tests.

In the test of static air pressures on different-sized diaphragms, the following was observed, using paper No. 2, Certificate bond (see par. 7):

Diameter, 1¾ inches; 16 pounds per square inch,
Diameter, 1¼ inches; 22.5 pounds per square inch,
Diameter, ¾ inch ; 37.0 pounds per square inch,

Plate VI. Diaphragm Blast Meter. Model 2.

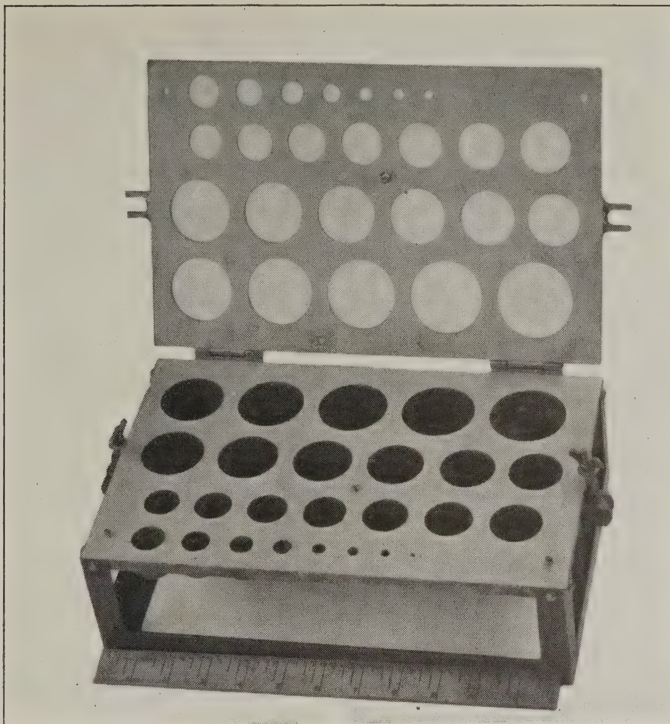


Fig. 1. Blast Meter, Open.

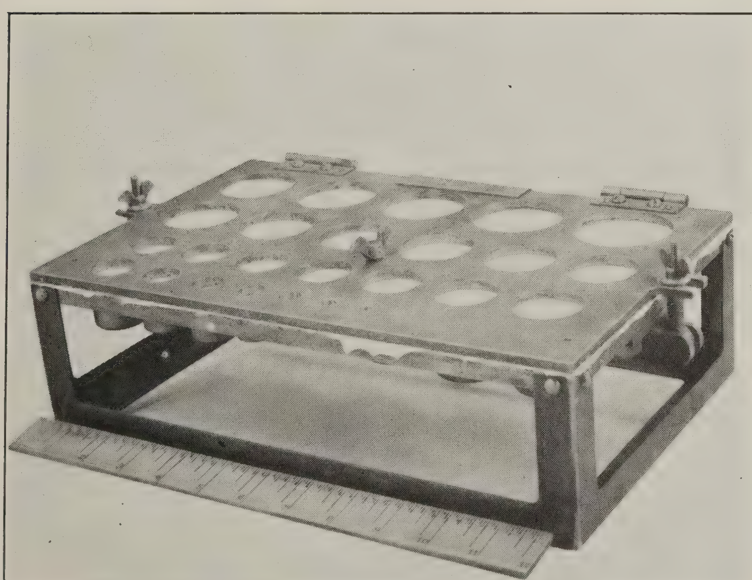


Fig. 2. Blast Meter, Closed: Diaphragm Clamped, Ready for Test.

these breaking pressures were inversely as diameters. For a $1\frac{1}{8}$-inch opening, the required pressure would be 27 pounds per square inch, just about equal to actual tests with Mullen machine for this paper.

12. *Relation of quantity of charge to force of blast.* In the case of actual blast, for small charges and short distances, not complicated by surrounding objects, the blow varies nearly directly with the quantity of charge, when fired in the open. But for large calibre gun discharge, many other factors, such as wave action, blast shadows, etc., enter the problem.

This relation of charge to force of blast can be well utilized in determining the strengths of different explosives and also to test the strength of various lots of the same explosive. For with a given weight of charge, distance and relation the same, the smallest size of diaphragm ruptured directly measures the strength of the charge. (See par. 19.)

13. *Relation of distance to force of blast.* It was attempted to determine the law of decrease of blow, as the distance from the origin increased, but tests were not made in sufficient number; it appears, however, that the decrease in blow did not vary inversely as the cube of distance. It apparently lay somewhere between the inverse of first and second power of distance. (See par. 17.)

14. *Reduced pressure, deflected wave and wind tests.* The question of suction or vacuum and back pressure was also investigated, and there is no doubt that the blow is much less in blast shadows, behind obstacles or around the corner, so to speak. For example, a test with the 155 mm. gun: charge, 24 pounds 12 ounces; height of muzzle, 5 feet; elevation, $0° 45'$; the 2 meters were placed at 100 feet, directly in front of muzzle. One, facing the muzzle, broke No. 9 diaphragm, $1\frac{1}{2}$ inch hole, pressure, 10.7 pounds: the other, back to the muzzle, no hole broke. General observation showed that this difference between front and rear blast was greater as the instruments were placed closer to the source of explosion.

In another case the meters were placed 50 feet directly in line of fire of a 240 mm. gun, diaphragms facing at right angles to plane of fire. Instrument No. 1 registered 25.6 pounds, and instrument No. 2, which had a 12-inch board forming an angle of 30° with plane of diaphragm, registered 32 pounds, showing the effect of a pocketed blow. It was also found that blasts taken with the

FIG. 1.

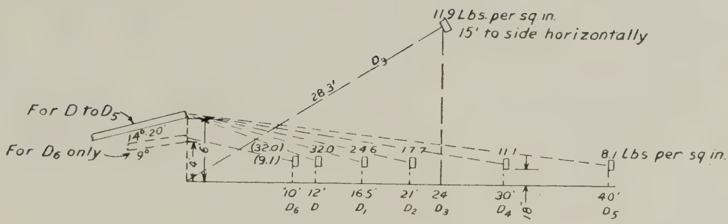


Fig. 1. Blast tests December 19, 1918, at Aberdeen Proving Grounds, Md., 4.7-inch gun, charge 5 pounds 3½ ounces, height of muzzle=6 feet, elevation 14° 20′, internal pressure=38,000 pounds per square inch.

The test D_6 was with a charge of 28 5/16 ounces, height of muzzle 4 feet, elevatin 9°: { Face pressure, 32.0 pounds; Back pressure, 9.1 pounds.

FIG. 2

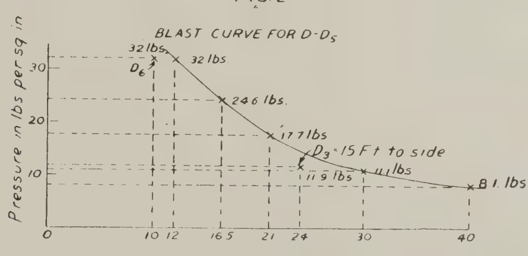


Plate VII. Blast Tests.

wind were somewhat greater than when against the wind. (See par. 18.)

15. *Tests with panes of glass, and open and closed boxes.* A test was made with small cubical boxes, 6 inches on a side, fitted with single thickness glass, 1/16 inch thick. Some boxes were open to the rear and some were closed. Those closed stood uniformly a slightly greater blow than those open, which was somewhat contrary to expectations, but it may be explained that the absence of a so-called back door created a suction or reduction of pressure on the far side of glass and thus really increased the blow. In the case of long sustained blasts at great distances from the source, open doors and windows may be a benefit in equalizing the pressure.

The 6-inch panes of glass were generally broken by a blow, corresponding to about 8 pounds of pressure per square inch. The strength of ordinary glass supported on two sides is given by Kent, page 343, as $w=\frac{3140 \quad bd2}{1}$. This is based on t. s. of glass=2560 pounds, with w=load at center, b=width, d=thickness and l= length, all in inches, and would give a uniform load of 1.1 pounds per square inch. Trautwine gives, on page 493, for uniform load on square plates, supported at four edges, as $S=\frac{3}{8}\,\frac{W}{d}2$, where d=thickness and s=tensile strength. By actual test, breaking 6-inch plates with total uniform distributed load, W was found to be 200 pounds, from which $S=\frac{3}{8}\times\frac{200}{\frac{1}{256}}=19200$ pounds maximum tensile strength. The actual uniform load, $w=\frac{w}{36}$, equalled 5.5 pounds per square inch, which is fairly close to the blast pressure recorded, considering the very un-uniform strength of glass. In making the tests with weights, the glass was found to rupture not instantaneously, but a few moments after the weight was applied. In the case of sudden air pressure the duration is appreciable, so that possibly slightly greater pressures than normal will be sustained before rupture.

Trautwine, on page 922, gives ultimate tensile strengths of glass as varying from 2,500 to 9,000 pounds per square inch, and it is generally known that the tensile strength for transverse loads increases greatly for thin plates of glass.

Blast tests, December 19, 1918, at Aberdeen Proving Grounds, Md., 150 mm. (6 inch) Howitzer, charge 8 pounds 5 ounces, height of muzzle=4 feet, elevation 16° 30′, internal pressure=35,000 pounds.

FIG. 1

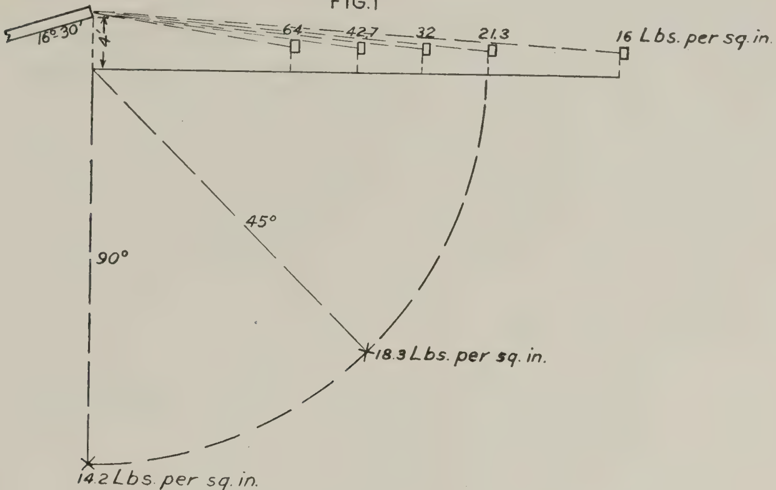


FIG. 2

BLAST CURVE

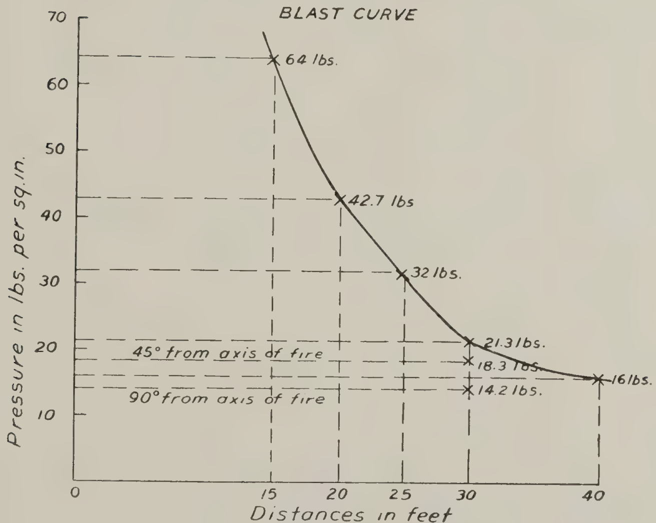


Plate VIII. Blast Tests.

16. *Endurance of human ears.* It was found that a break of 5/8-inch diaphragm, corresponding to 25.6 pounds per square inch, was approaching the maximum blast for the human ear. This pressure of 25.6 pounds, plus atmosphere of 14.7, made a total of 40.3 pounds or about 2¾ atmospheres, or about equal to ordinary safe driving pressures. The blow of 25.6 pounds was roughly tested by dropping small bags of shot, 1.2 ounces in weight, through a 5/8-inch cylinder, 1 foot long, corresponding to .075 foot-pound on a 5/8-inch diaphragm or area of .307 square inch or 2.4 foot-pounds per square inch. As far as blows or concussion in air are concerned, however, it appears best to measure all blasts in resultant pressures pounds per square inch, and not in energy of blow of foot-pounds per square inch.

17. Some actual tests:

I. Relation of blow or pressure to distance—

(a) 1 pound T.N.T., meters and explosive 3 feet above ground;

At distance D=15 feet; P=22.5; C=Constant=.93
At distance D=20 feet; P=15.75,

$$P_1 = P \times \frac{D}{D_1} \times C = 22.5 \times \frac{15}{20} \times .93 = 15.75 \text{ pounds.}$$

(b) 1½ pounds, 40 per cent dynamite;

At 10-foot distance P=31.5, C=.94 (coefficient);
At 15-foot distance P_1=19.7;

$$P_1 = 31.5 \times \frac{10}{15} \times .94 = 19.7 \text{ pounds.}$$

(c) 2 pounds, 40 per cent dynamite;

At 15-foot distance D=15, P=26.25; C=.94;
At 20-foot distance D_1=20, P_1=18.5;

$$P_1 = 26.25 \times \frac{15}{20} \times .94 = 18.5 \text{ pounds.}$$

From the above we see that the blow varies about inversely as the distance.

II. Tests as to gun discharge:

(d) Gun discharge: at Aberdeen Proving Ground, December, 1918, 4.7-inch gun; charge, 5 pounds 3½ ounces; height of muzzle, 6 feet; elevation, 14° 20′; internal pressure, 38,000 pounds. Two meters were used in all positions 18 inches above ground, and directly in vertical plane of fire, except in D_1 meters were on ground and in D_5 they were placed 15 feet to side and 29 feet from muzzle. Pressures are the mean for each position.

Plate IX. Blast Tests.

Fig. 1. Blast tests December 1, 1918, at Aberdeen Proving Grounds, Md., 240 mm. (8-inch) gun, charge for D to D_6=40 pounds 4 ounces, and for D_7 to D_{16} 42 pounds 5 ounces, height of muzzle=6 feet, elevation 15° 8′.

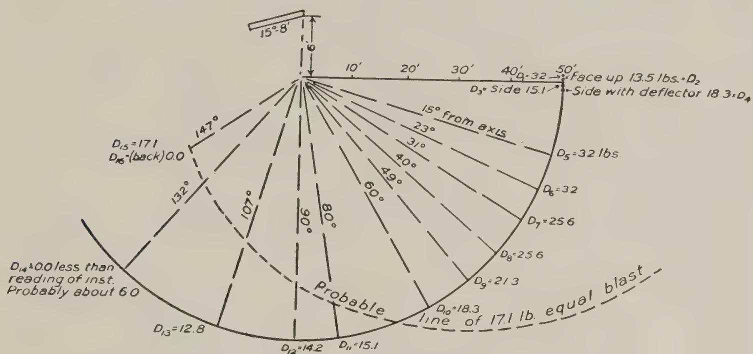
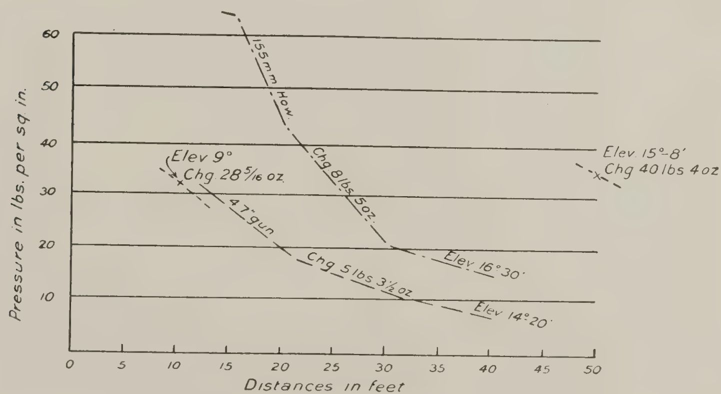


Fig. 2. Comparison of blast pressures of 4.7-inch gun, 150 mm. Howitzer and 240 mm. gun with different charges and at different elevations.



Distances in feet.

From the above, we see how the blow increases with the charge, but less rapidly.

	Feet.	Pounds.	
Distance	$D=12$	$P=32$	$P_1=P\,\frac{D}{D_1}\times C$
	$D_1=16.5$	$P_1=25.6$	$C=1.1$
	$D_2=21.0$	$P_2=18.3$	$C_2=1.0$
	$D_3=30.0$	$P_3=12.2$	$C_3=.95$
	$D_4=40.0$	$P_4=8.2$	$C_4=.85$
	$D_5=29.1$	$P_5=12.4$	$C_5=.94$
	$D_6=10.0$	$P_6 \begin{cases} \text{face}=32.0 \\ \text{back}=9.1 \end{cases}$	

Special case, elevation=9°, charge 28 5/16 ounces.

Diagram of positions and curve of blast are shown on Plate VII, Figs. 1 and 2.

(e) Gun discharge, 155 mm. howitzer; charge, 8 pounds 5 ounces; height of muzzle, 4 feet; elevation, 16° 30′; internal pressure, 35,000 pounds square inch. Positions of meters, 18 inches above ground and directly in front of muzzle, except D_6 which was at angle of 45° from direction of muzzle and D_7 at right angles to direction of fire. Pressures are the mean for the positions.

	Feet.	Pounds.		
Distance	$D=15$	$P=64$		
	$D_1=20$	$P_1=42.7$	$C=.87$	Coefficients by trial.
	$D_2=25$	$P_2=32$	$C=.83$	
	$D_3=30$	$P_3=21.3$	$C=.65$	
	$D_4=30$ at 45°	$P_4=18.3$		
	$D_5=30$ at 90°	$P_5=14.2$		

It will be seen that in the cases, *d* and *e,* the blows decreased more rapidly than the inverse of the distance. (See Plate VIII, Figs. 1 and 2.)

18. *Tests as to direction from muzzle.* At Aberdeen, Md., December, 1918, 240 mm. gun; charge, 40 pounds 4 ounces; height of muzzle, 6 feet; elevation, 15° 8′; meters on ground, various positions around circle, facing toward muzzle except D_2 facing up and D_3 and D_4 sidewise and D_{16} back blow. Azimuths are given from direction of fire.

	Ft.	Az.		Blow lbs. sq. in.
Distance	D_1 =50	0°		32
	D_2 =50	0°	face up	13.5
	D_3 =50	0°	side	15.1
	D_4 =50	0°	side, blow with deflector	18.3
	D_5 =50	15°		32
	D_6 =50	23°		32
	D_7 =50	31°		25.6
	D_8 =50	41°		25.6
	D_9 =50	49°		21.3
	D_{10}=50	60°		18.3
	D_{11}=50	80°		15.1
	D_{12}=50	90°		14.2
	D_{13}=50	107°		12.8
	D_{14}=50	132°		0.0[a]
	D_{15}=25	147°		17.1
	D_{16}=25	147°	back	0.0[a]

Diagram of positions are shown on Plate IX, Fig. 1.

The blast pressures during this test around the circle of 50-foot radius remain quite uniform until about 30° from direction of fire. At 90° from direction it is less than half, and at 132° it becomes very small, less than 8 pounds.

A comparison of the blasts of different guns is shown on Plate IX, Fig. 2. It will be seen that the blow varies with the caliber and charge, but less rapidly than the increase in charge.

19. *Tests as to strengths and quantity of explosives.*

Test No. 1. 1 pound charges with No. 8 electric caps. All on ground.

	Distance.	Strength of paper.	Smallest diap. broken.	Blast pressure.
	Feet.	*Mullen pts.*	*Inches.*	*Lbs. sq. in.*
1 lb. T.N.T.	15	27.5	1 1/2	20.67
1 lb. Anilite (7/3) liquid	15	27.5	1	31
Do.	10	27.5	5/8	49.6

Ratio of Anilite to T.N.T.=about 1½ to 1.

[a]Zero readings indicate that the blow was less than 8.0 pounds, the pressure required to break the 2-inch diaphragm.

Test No. 2. All 3 feet above ground, at 20-foot distance.

	Distance.	Strength of paper.	Smallest diap. broken.	Blast pressure.
	Feet.	*Mullen pts.*	*Inches.*	*Lbs. sq. in.*
1 lb. T.N.T.	20	17.5	1 1/4	15.75
1 lb. 40 per cent dynamite.	20	17.5	1 13/16	10.90
2 lbs. 40 per cent dynamite	20	17.5	1 1/16	18.50
3 lbs. 40 per cent dynamite	20	17.5	14/16	22.50

Ratio of 1 lb. T.N.T. to 1 lb. 40 per cent dynamite=1.44 or 1.44 per lb.
Ratio of 1 lb. T.N.T. to 2 lbs. 40 per cent dynamite= .82 or 1.64 per lb.
Ratio of 1 lb. T.N.T. to 3 lbs. 40 per cent dynamite= .57 or 1.71 per lb.

Test No. 3. All 3 feet above ground, at 15-foot distance.

	Distance.	Strength of paper.	Smallest diap. broken.	Blast pressure.
	Feet.	*Mullen pts.*	*Inches.*	*Lbs. sq. in.*
1 lb. T.N.T.	15	17.5	14/16	22.5
1½ lbs. 40 per ct. dynamite	15	17.5	16/16	19.7
2 lbs. 40 per ct. dynamite..	15	17.5	12/16	26.3

Ratio of 1 lb. T.N.T. to 1½ lbs. 40 per cent dynamite=1.14 or 1.71 per lb.
Ratio of 1 lb. T.N.T. to 2 lbs. 40 per cent dynamite= .86 or 1.72 per lb.

In all the above tests the observations are fairly close and I am convinced that, taken with more uniform papers and under more careful conditions, the strengths of explosives weight for weight can be very accurately measured.

20. *Résumé.* The tests so far made indicate the following:

(a) That a blast effect is equivalent to a banked-up gaseous pressure pounds per square inch, as far as breaking or shattering is concerned;

(b) That this blast pressure can be measured by destructive action on diaphragms of paper or similar material placed over various sized holes, preferably closed at bottom;

(c) That the blow at short distances varies generally as the quantity of charge;

(d) That the blast pressure under similar conditions varies inversely as the diameter of smallest diaphragm ruptured;

(e) That at short distances the blow decreases, generally inversely as the first to second power of distance;

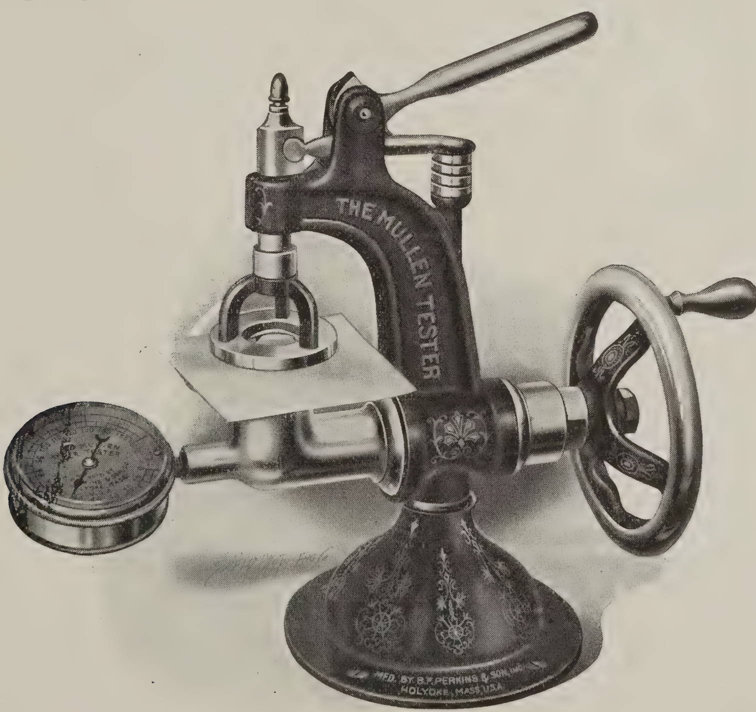
(f) That the blast pressure obtained under similar conditions will measure the strengths of different explosives or of various lots of same explosive, weight for weight.

21. The following additional investigations are desirable:

(a) By placing delicate electric circuits in the diaphragms, the time of breaking of the various diaphragms in the same meter and in meters at various locations can be determined, and thus the speed and duration and maximum amount of blast pressure determined.

(b) For this purpose about 25 meters should be made as indicated in par. 8, and simultaneous readings be taken at different positions and distances from the source of explosion, and thus a curve of blast be more fully developed than at present possible.

(c) That tests be made with very thin metal diaphragms of uniform strength, thus eliminating any moisture effect on the diaphragm.



Mullen Tester.

GENERAL BEAUREGARD.

By

Rev. James E. Duffy.
Chaplain, U. S. Army.

Pierre Gustave Toutant Beauregard was born of one of the oldest and most illustrious families in Parish of St. Bernard, in New Orleans, La., on the 28th of May, 1918. Toward the end of the 16th century the last male descendant of the Toutant family died, leaving an only daughter who married Sieur Paix de Beauregard, hence the family name Toutant de Beauregard. Jean Toutant was the first of the name to come to Louisiana. He married Madeline Cartier, to whom three sons were born. One of the sons, Louis Toutant Beauregard, married the daughter of a noted planter of St. Bernard's Parish of New Orleans, to whom a daughter and two sons were born. The younger son, Jacques Toutant Beauregard, married in 1808 Miss Helene Judith de Reggio. Several children blessed their home and the third was Pierre Gustave Toutant Beauregard.

The maternal ancestry is more illustrious, he being a descendant of the Dukes of Reggio and Modena, of the House of Este.

The mother of General Beauregard was the daughter of Emanuel Chevalier de Reggio and Louise Olivier de Vezin. At the age of 11 Beauregard was taken to the city of New York and placed under the tutelage of the Messieurs Peugnet, Captains of the French Army, the one of Cavalry the other of Engineers. Living in such an environment for four years, he imbibed the spirit of military life.

His parents opposed his choice of vocation, but finally yielded to his wishes and at the age of 16 Pierre Beauregard entered West Point. He was second in a class of 45. Persistence in everything pertaining to his course was his watchword. At the age of 20, on July 1st, 1838, he was graduated with high honors. Among his classmates were Generals Wayne, Ed. Johnson, Reynolds, Hardee, Stevenson and Trapier and Sibley of the Confederate Army, and McDowell, A. T. Smith, Granger, Barney, and McKinstry of the

Federal Army. July 7th, 1838, he was commissioned 2nd Lieutenant in the U. S. Engineers.

In 1846 he directed, under his own plans, the fortification of works at the city of Tampico. In March, 1847, he joined the expedition under Major General Scott against the City of Mexico. He distinguished himself at the Siege of Vera Cruz and in most of the battles in the valley of Mexico. In 1847, after considerable deliberation on the part of his superior officers, Beauregard's opinion regarding point of attack against Mexico was acted upon.

Beauregard was twice wounded at Belen Gate. After the Mexican War he returned to his home. He was breveted Captain, August 20th, 1847; was breveted Major September 13th, 1847.

Beauregard had determined to retire from active service. What a distinct loss such a move would have been, this letter will show.

"New York, *Dec. 9th, 1856.*

"Major G. T. Beauregard, U. S. Engineers:

"My dear Sir—I am much concerned to learn that you think of leaving the army. . . . Your brilliant services in Mexico, nobody who witnessed them can ever forget. They bind the affections of the army to you, and ought, perhaps, to bind you to us.

"WINFIELD SCOTT."

Fortunately, Major Bèauregard remained in the service. From 1853 to 1861 he was in charge of what was then called "The Mississippi and Lake Defenses in Louisiana." In 1860, Beauregard, aged 42, was appointed Superintendent of West Point, at which place he could show how thoroughly he knew Man. A month after his appointment, as Superintendent, he resigned and in February, 1861, entered the Confederate service, with rank of Brigadier General.

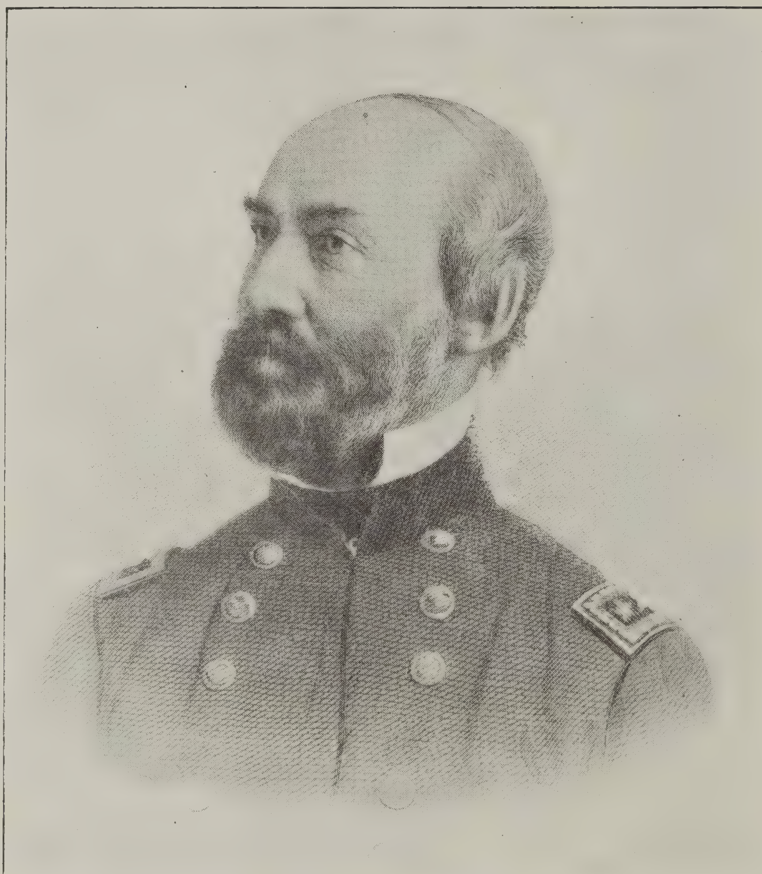
We can truthfully say that the part he played in that historical drama was chosen because he felt it was just. Despite the fact that his resources were most inadequate, yet withal for nearly two years he held over 300 miles of most vulnerable coast versus onslaughts of land and naval forces. When the news reached the South that Major Beauregard had resigned his commission the scene was nothing short of tragic. At a convention held in South Carolina it was decided that Beauregard was to assume charge of Charleston fortifications. It dawned on him that his resignation was not accepted. Had the President refused to countenance his resignation, we feel that Beauregard as a true soldier would have bowed his head to the inevitable and obeyed.

We will follow Beauregard into the battlefield. April 12, 1861, failing to obtain a peaceful evacuation of Fort Sumter, General Beauregard ordered the Fort to be fired upon, and firing continued till Sumter fell April 13th, 1861.

July 21, 1861, shortly after his victory at Sumter, Beauregard defeated his classmate, General McDowell, at Bull Run. February, 1862, he took command of the Army of the Mississippi. About this time, Johnston died and Beauregard took command. At the battle of Shiloh or Pittsburgh Landing, the Federals under Grant were surprised by Confederates under Beauregard and forced back to the River, 6th of April, 1862. On the 7th, Grant, reinforced by Buell's Army, drove the Confederates from the battlefield. Being outnumbered, Beauregard's success lay in withdrawing to Corinth, where he held forth against the superior forces of Halleck till May 30th, when he evacuated it, making hasty retreat to Tupelo. He afterwards commanded the defense of the Southern Coast, signalized by the unsuccessful attack, April 7th, 1863, of Admiral Dupont's squadron and by the combined operations of sea and land forces under Admiral Dahlgren and General Gilmore. In 1864 he resisted successfully General Butler's forces at Drurys Bluff. With only 10,000 men he withstood General Grant's attack upon Petersburg, holding that place till reinforced by part of Lee's Army and thus compelling the long protracted siege. He was charged with resisting General Sherman's March to the Sea, having only 5,000 men. The skillful withdrawal of General Hardee's Army from Savannah was due to Beauregard. He was tendered chief command of the Army of Roumania, 1866, and that of the Egyptian Army, 1869, both of which he declined. Adjutant General of State of Louisiana, 1878 to 1887. Commissioner of Public Works of New Orleans from 1888 to 1891. Died in New Orleans February 20th, 1893.

Beauregard loved his work, he loved his men. He was kind, considerate of the feelings of those under him. He was a born leader, an engineer of rare ability, a man among men, a man that closed a deaf ear to the praises and plaudits of the world, a man whose watchword was not ''Go'' but ''Follow,'' for he was ever in the lead. His defense of Charleston Harbor will ever stand as a monument to his engineering skill and ability. When the cause for which he so nobly and honestly fought was lost, he returned to his home in New Orleans.

THE LIBRARY
OF THE
UNIVERSITY OF ILLINOIS



GEN. GEORGE W. CULLUM
1809-1892

FINAL REPORT OF FLASH AND SOUND RANGING SERVICE

A. CHRONOLOGICAL.

On the entry of the United States into the war in Europe, there existed no service in our army at all analogous to those which had grown up under the conditions of position warfare in Europe since the Autumn of 1914 for the purpose of accurately locating the positions of active enemy artillery and for directing the fire of the friendly artillery on these positions.

The location and ranging by means of sound was entirely new. The location by means of visual observation, though it might be regarded as an outgrowth of methods already practiced, was rendered so complicated by reason of the great artillery activity that special synchronizing devices had to be adopted and the personnel especially trained for this new and more elaborate visual observation.

In the early spring of 1917 a commission of French technical officers was sent to the United States to explain the various new devices which had come into use in the French Army since 1914. Many of these devices had to do with the Air Service which, in the spring of 1917, was an activity of the Signal Corps—others had to do with wireless which was also a Signal Corps activity. Possibly for the reason that the greater part of the work of the French Commission lay with the Signal Corps, it was decided in Washington to place the Sound and Flash Ranging under the Signal Corps although in so doing an important departure was made from French practice which was to place the technical control and training of the Ranging personnel with the Topographic Division (*Service Geographique de l'Armee*) and the tactical control with the Army Artillery. On the advice of the French commission, the Chief Signal Officer ordered a competitive trial of the four types of Sound Ranging apparatus in use on the French front and charged Major (now Lieutenant Colonel) Augustus Trowbridge with the supervision of the construction of an instrument of each type from drawings, photographs, etc., brought to America, by the French Commission and the subsequent comparative test of the instru-

ments at a proving ground. The members of the French Commission were pressed for an expression of opinion as to the relative merits of the various systems. They were either unable or unwilling to give an expression of opinion and strongly urged experimentation in America. The weight of this authority prevailed against the other, and, as it now appears, wiser, council which was to send to France an officer whose sole duty it should be to investigate the organization and functioning in the fiield of the various systems of Sound Ranging and the organization of the French and of the British Flash Ranging and return to the United States to supervise the construction of instruments and the training of personnel.

By following the advice of the French Commission too much stress came to be laid on experimentation and too little on organization and further a proper appreciation of the importance of Flash Ranging was delayed because the technical problems, which the French Commission had stressed, were far simpler for Flash than for Sound Ranging.

The greater part of the months of July and August, 1917, were used in the construction and test at the proving grounds at Sandy Hook, N. J., of Sound Ranging apparatus. The organization for this experimental and testing work was as follows: The National Bureau of Standards, Washington, D. C., undertook to construct two of the systems in use by the French, viz, The Cotton-Weiss and the T. M. Dr. E. B. Rosa of the Bureau of Standards was in charge of this work and had the assistance of a number of young civilian employees of the Bureau of Commerce and Labor, two of whom afterwards entered the Army and came to France with the troops which carried on the Ranging service in the American E. F.

Dr. (now Captain) H. B. Williams, undertook the construction in the Physical Laboratory of Princeton University of the other two systems in use on the French front, viz, The Defour and The Bull-Tucker. In this work he was assisted by a number of physicians of Princeton and other universities who were able to devote their summer vacations to this work. Three of this group later entered the Army and two of these came to France, among the first to be engaged in the Ranging with the American E. F.

The comparative tests of the four instruments which was held at the Ordnance proving grounds in August, 1917, resulted in a unanimous opinion that the Dufour apparatus performed best,

had the greatest reserve sensitivity and embodied the greatest number of good features which had been stressed by the French Commission.

From the purely technical point of view, this opinion was well founded but, as stated above, undue stress had been laid on the technical side by the French Commission which was made up largely of technical men who had had little or no experience at the front, and for this reason the decision made at the proving grounds turned out to be unwise.

Major Trowbridge recommended to the Chief Signal Officer that work be commenced on three sets of apparatus, System Defour, and that he and one other officer be sent to France to study the problem of organization and return on completion of this duty to undertake quantity production of apparatus and enlistment and training of personnel. This was approved and Major Trowbridge and Captain (now Major) Theodore Lyman arrived in France and reported to the Chief Signal Officer about the end of September, 1917.

Prior to this date General Orders No. 8, American Expeditionary Forces, 1917, had placed the Sound and Flash Ranging in the Topographical Division of the Intelligence Section of the General Staff under the direction of Major (now Colonel) R. G. Alexander, Corps of Engineers. Major Alexander had sent the only men available at the time, two very intelligent engineer soldiers, to the French school for Sound Rangers and later to French Sound Ranging Sections at the front and, realizing the need of some officers with expert knowledge of Physics and Mathematics in the Sound and Flash Ranging Service, had secured the Commission from Civil life of Lieutenant (now Captain) C. B. Bazzoni, a very able young American Physicist who happened to be in Europe at the time. Lieutenant Bazzoni was sent to visit a number of French Sound Ranging Sections and later, in September, 1917, to visit the British sections, the organization and equipment of which had not at that time been studied by any officer connected with the establishment of a ranging service for the A. E. F.

On the arrival of Major Trowbridge and Captain Lyman at American Headquarters they were ordered to report to Lieutenant Colonel (now General) Nolan and were later transferred from the Signal Corps to the Engineers. After visiting a number of French Sound Ranging Sections and two French Flash Ranging Sections they were ordered to British Headquarters for a careful study of

the British methods, organization and equipment. As the result of the extended comparative study of the French and British ranging methods by Major Trowbridge, Captain Lyman and Lieutenant Bazzoni, it was decided by Major Alexander to recommend to the Chief of Engineers, Washington, that the work begun by the Signal Corps, in America, on Sound Ranging apparatus be stopped and that construction be begun on apparatus of the type in use by the British—that as regards the Flash Ranging, the French system be copied by the A. E. F.

Major Trowbridge was charged with making arrangements with the British and French whereby sufficient material for the needs of the A. E. F. be secured until a satisfactory supply from America was obtained. A messenger was sent to the United States in November with blue-prints and specifications needed for the construction of both the Sound and Flash Apparatus in America. Owing to mishaps at sea and delays in embarkation, this messenger did not arrive in Washington until the middle of January, 1918, and this caused delay in the final delivery of the American-made apparatus. This delay, however, caused not the slightest detriment to the service, thanks to the very cordial assistance rendered by the British Sound Ranging Service and to the fact that ample quantities of French Flash Ranging Apparatus had been provided for on the original estimates of material needed from French sources.

By March, 1918, the most urgently needed special supplies were arriving from the United States, and by September, 1918, all items on requisition in the United States were coming in quantity.

2. *The period from October, 1917, to March, 1918, was one of organization and the Training of Officers and Enlisted Men.*

There were no young Engineer officers nor any Engineer troops in France immediately available in the early autumn of 1917. There were, however, a large number of young Americans in France who had been in the American Ambulance Service with the French Army and, of these, many with the necessary education and qualifications were seeking enlistment of commissions in the American Expeditionary Force. A large number of these young men were interviewed by Major Alexander or by Major Trowbridge or both, and in this way four very valuable young officers were secured at an early date. Three other extremely efficient young officrs were released from other duty at General Headquarters, and one arrived from Captain William's detachment at Princeton, New Jersey,

as a casual. These officers were all sent for study of Sound or Flash Ranging at the British schools and for subsequent front line experience at the British Ranging Sections where they remained until they were needed to train the first detachment of American Sound and Flash Ranging troops.

On December 20, 1917, 40 enlisted men of the 116th Engineers were ordered to the Army Engineer Schools, Langres, to prepare a Sound and Flash Ranging School against the time when the 1st Ranging Company should arrive from the United States for instruction. This detachment was subsequently incorporated in the various Sound and Flash Ranging Sections on the American front and proved an invaluable nucleus of high-grade, well-trained men.

This school detachment, under command of Captain Lyman, assisted by Lieutenant Bazzoni, was installed at Fort St. Menge, north of Langres, by the 1st of January, 1918. The fort, which had been unoccupied when turned over by the French, was gotten into condition to serve as quarters and school; and the men were trained in the theory and practice of ranging by the officers and the two enlisted men mentioned above as having had Sound Ranging experience with French Sections. Instruments for both Sound and Flash Ranging had been procured from the British and the French and the men had about six weeks' instruction in theory and practice before the first company of ranging troops arrived from the United States.

When this company (Co. B, 29th Engineers) arrived in France in the middle of February, 1918, it was found to contain mixed ranging and printing and survey troops. Those with printing and survey experience were at the time most urgently needed for the work of the Base Printing Plant at Langres. These were detached from Company B and the deficiency made up by the 40 men from the 116th Engineers mentioned above and additional replacements which were authorized. The officers of Company B, not technical printing or survey men, and about 20 casual officers who had been selected for attachment or assignment to Co. B, were sent either to the British Sound or Flash Ranging schools with subsequent front line experience at the sections or to French Flash Ranging Sections after theoretical and practical training at the Army Engineer Schools at Fort St. Menge.

These officers were kept at the British and French fronts until they were needed to officer the American Sound or Flash Sections

as they were formed. In addition to the officers, a few of the best of the enlisted men were sent after training at the American School to British Sound Ranging Sections at the front. Early in March, 1918, the first American section was established at the front. This was Sound Ranging Section No. 1 (under Captain Bazzoni) which occupied a position in the sector then held by the 1st American Division in the region northwest of Toul. About the same time a detachment of Flash Ranging troops under Lieutenant (now Captain) Wright was detailed to serve with a French Ranging Section in the same sector with the object of ultimately taking over from the French the responsibility for visual observation and Flash Ranging in this region which was to become an all-American Sector.

With the establishment of the first ranging section at the front the period of preparation came to an end.

It is possible at this writing to estimate in the light of subsequent events the failing and the successes of the preparations made in the period from October, 1917, to March, 1918.

EQUIPMENT.

Instead of planning for the manufacture of the technical equipment in the United States, a better plan would have been to bring over machinists with tools and raw materials and to do the small amount of manufacture in France where easy contact would have been assured between those making, and those using, the technical equipment. This plan was discussed and rejected partly because of advice from the British officers not to count on being able to secure any materials in the French market and partly because of the difficulty of securing machinists from America qualified to do the rather delicate work required. It appeared at the time that the proper type of machinist could only be quickly secured as civilian employes and there was at the time no provision for the overseas shipment of civilian employes. Had it been more fully realized how great a barrier to the carrying out of plans the ocean interposed, a determined effort to provide for the manufacture in France of the more technical part of the equipment would have been made or, failing that, provision would have been made for the return to America of one or more officers thoroughly conversant with the practical working of the Flash and the Sound Ranging Sections at the front.

As it turned out, due to the great assistance rendered by the British, no case arose where equipment was lacking when trained personnel was ready for the field, but had the plan outlined in the last paragraph been followed, time, effort and expenses would have been saved.

PERSONNEL.

The method of training the personnel was highly satisfactory and under the circumstances it would seem that no better could be adopted.

The conditions pertaining were, however, very favorable for training, viz, 1st, an exceptionally high grade of enlisted men in the first American units to arrive; and 2nd, leisure, before it was possible to begin the training of these men (owing to transport shortage) to thoroughly train with our allies a carefully picked body of capable enthusiastic young officers to serve first as teachers of the men and later to command them.

It should be remarked here that although the Sound and Flash Ranging School was officially a branch of the Army Engineer Schools, the training of the troops was, with the hearty consent and coöperation of the Commandant of these Schools, entirely planned and carried out by officers of G-2-C, G.H.Q., and the necessary equipment, supplies and labor were furnished by a Battalion of the 29th Engineers operating under orders of G-2-C. It is believed that in the case of so highly technical and special a service it is absolutely necessary that those responsible for the operation in the field have complete control of the training of the troops.

The reports of the officers of the Sound and Flash Ranging Service, reports for the most part made during the period of training prior to March, 1918, are accessible in the files of G-2-C, G.H.Q., American E. F. These reports bring out clearly the general opinion as to the superiority of the British over the French Sound Ranging Service and also contain much of interest on the organization of both the French and British Flash Ranging Services.

The list of these reports with the identification numbers assigned to them follows:

Sound Ranging.

1. By Captain Bazzoni.—Visit to French Sound Ranging School and French Sections, August 29, 1918.

2 and 3. By Captain Bazzoni.—Visit to three French Sound Ranging Sections, September 3rd, and September 19, 1918.

4. By Captain Bazzoni.—Preliminary Report on British Sound Ranging Service.

5. By Lieutenant Colonel Trowbridge.—Report on British Sound Ranging Service with attached Report from Major Lyman.

Other reports on instruction at British school and front line sections by Captain French and Lieutenants Fecht, Beckett, Mitten and Wallower. Also a report by the last-named officer of personal experiences during the retreat with a section of the British 5th Army in March, 1918.

Flash Ranging.

6. By Captain Wright—A very full report on organization and operation of British Flash Ranging Sections, January 21st, 1918.

7. By Major Pendleton—On visit to a French Flash Ranging Section, January 29, 1918.

8. By Captain Whitney—Valuable report on the present proposed organization of the British Ranging Service, October 18, 1918.

By Capt. B. A. Ross—Report on British School and Front-Line Section, January 19, 1917.

3. *The period from March, 1918, to August 20, 1918*, was one during which the Ranging Sections, though organized as Army troops were operating with American Divisions or Corps or under French Corps in sections partly held by American troops. The events following the beginning of the German offensive, in March, delayed the schedule of the formation of the American units into Corps and Armies and retarded the overseas movement of special troops and thus incidentally retarded the development of the Sound and Flash Ranging Service.

Prior to this, however, and anticipating the formation of an American Army in the Toul Sector, one American Sound Ranging Section had been installed and was reporting to the nearest French Corps Artillery Information Officer. This first section was dependent on G. H. Q. for all its technical and most of its general supplies, except rations, which it drew from the nearest American Division. This management, though not contemplated in the general organization, worked so well that it was decided to increase the

number of sections in the sector up to the limit of the number which could be made out of the one company which had arrived in France and was trained. Captain Lyman was put in charge of this Company, which furnished three Sound and one Flash Ranging Section. Captain Lyman made his headquarters at those of the Division which happened to be occupying the sector and when the Division moved out his orders were changed by G. H. Q., so that his company remained in the sector.

The original plan of organization was to have a Battalion of five companies (maximum) with each Army so as to provide one company for each Corps constituting the Army. Each of these companies was to be broken up into four sections, two Sound and two Flash or three Sound and one Flash, dependent on the nature of the terrain on the particular corps front or on the character of the enemy artillery in the sector.

For position warfare it was generally conceded that both the Sound and Flash Ranging secions should remain in the sector even if the Corps should move and it was for this reason that the Ranging Battalion was attached to the Army rather than the Ranging Company to the Corps. It was not until August, 1918, that this proposed organization could be perfected, for during the period of the German offensive, sections had to be moved from one sector to another whenever it seemed that the Artillery might best employ them.

During this period of the German offensive the policy was adopted of placing newly trained sections in the relatively quiet Toul sector with the view of relieving the more experienced sections to be available with American troops on the active Chateau Thierry sector. One experienced Flash Section and one fairly experienced Sound Section were transferred in June to the active sector and both were in operation before the 18th of July when the Allied counter-offensive began. The Flash Ranging Section rendered very valuable services both before and after July 18th—the Sound Ranging Section also did well before the counter-offensive began but was unable to follow the swift advance towards the Vesle and was withdrawn to the Toul Sector.

This should not be taken to imply that a Sound Ranging Section need necessarily be less mobile than a Flash Ranging Section. It is, however, less useful *during* mobile warfare than a Flash Section, though it should be of the greatest use in the period just preceding

an advance in locating the larger calibre of the enemy Artillery. The reason why the Flash Section is the more useful during mobile warfare is that the enemy Artillery then takes up temporary positions with less attempt at concealment and there are in action fewer concealed large caliber enemy guns, for locating which Sound Ranging is best adapted.

In August, 1918, when the Army organization was completed, all the American Ranging sections were collected in the Army area and the location of the enemy Artillery in the St. Mihiel Salient was undertaken in preparation for the American offensive in that sector. Meanwhile Companies C and D of the 29th Engineers had arrived in France and the 2nd Battalion of the 29th Engineers was formed, August 20th, with Captain Lyman as Major of the Battalion.

The greater number of sections at the front had necessitated enlarging the facilities both of the School and of the technical supply depot. This latter, which had been originally located at the school, was moved to Langres which was both nearer to rail transportation, and, being the Headquarters of the 1st Battalion, 29th Engineers, permitted the institution of obvious economics in personnel and transportation. There was a daily courier service for large quantities of maps from the Base Printing Plant to the Army Headquarters and advantage was taken of this in sending technical supplies to the various ranging sections in the Army area.

By the time the 2nd Battalion Headquarters was formed, the whole system of training, technical supply and operation was working smoothly except for the fact that none of the sections had sufficient transportation. Scarcely enough transportation was allowed for in the tables of organization and at no time was the Battalion in possession of half of the authorized amount.

The Period from August 29th to November 11th, 1918, was one during which the ranging sections were operating in practically an American Sector as Army troops and thus practically as contemplated in the original plans. During this period the St. Mihiel offensive was carried out and because of the success of this operation an opportunity was offered of judging of the results obtained by the sections in locating the enemy Artillery in this region. A separate report on this matter is given in an appendix to this report and will be discussed later. On September 12th, the date on

which the St. Mihiel offensive started, there were in the field three American Sound Ranging and two Flash Ranging Sections.

Profiting by the experience gained in the Chateau Thierry offensive, provisions had been made for making the sections as mobile as possible and the results were satisfactory. On account of the narrowing of the front as the line advanced, one Sound Ranging Section did not need to advance and was held in reserve. One of the Sound Ranging Sections was in operation for a short time 36 hours after the offensive started and in operation in what proved to be a permanent position after 60 hours. The other Sound Section and both Flash Sections also kept up well with the advance.

When the line stabilized and new sections trained at the school went to the Army in the Toul Sector, the policy was adopted of establishing sections to both the right and left of the positions already occupied. The Sound Ranging Sections were so disposed that three or four individual sections could be grouped so as to form a single section of every broad base. This group of sections was so laid out that it was favorably oriented for the location of the larger caliber enemy guns in the region of Metz.

The idea of so grouping the sections was excellent and it would in all probability have proven well worth while had a siege of Metz been undertaken. As it was the group of three Sound Ranging Sections was used a few days before the Armistice went into effect in an attempt to range the American Railway Artillery on Conflans as an objective. The distance from Conflans to the nearest Sound Ranging instrument was 22 kilometers and under favorable weather conditions it was thought that it might be possible to record the burst of a shell at that distance. The bombardment of Conflans was naturally a part of the Artillery program and took place without reference to what would have been favorable conditions for Sound Ranging at such great distance—that is, a gentle wind blowing from Conflans towards the American lines.

It happened that the conditions were quite unfavorable for success at the time of the shoot. No test having been possible under good conditions it can only be concluded that ranging over so great a distance is impracticable with the present instruments.

The employment of a series of sound ranging sections to give one section of very long base is quite feasible, however, for locating enemy Artillery, since the report of a long-range gun is far more powerful than the burst of its shell. Whenever possible Sound

Ranging Sections should be laid out and interconnected so as to form if desired a single section for the purpose of locating long range enemy guns or of carrying out the ranging of the friendly long range Artillery on objectives as far in the rear of the enemy front line as it may prove possible to range.

When the offensive in the Argonne began one Flash Ranging Section was detached from the 2nd Army which then occupied the Toul Sector and at the request of the Corps Artillery attached to the 1st Army. The sector covered by the 1st Army was provided with French Flash Ranging Sections and for this reason the American section was held in reserve against the time when a rapid advance should be made. This American section had been especially trained for mobility and had already operated with the Corps to which it was attached in the mobile warfare around Chateau Thierry. When the final advance to the Meuse near Sedan took place, this section was on the left and had the greatest distance to cover. It got into position just as the Armistice was concluded. When the Third Army was formed the Artillery of the 4th Corps requested that this section be sent forward with them on the march to the Rhine. Another Flash Ranging Section also accompanied the Artillery of the other Corps (the 3rd) of the Third Army. At the time of the signing of the Armistice there were in the field five Sound Ranging Sections, of which four were operating, and an equal number of Flash Ranging Sections. There was one Company (Co. F, 29th Engrs.) at the School, about two-thirds trained and provided with full equipment to take the field in about two weeks time.

There was on hand at the depot ample supplies for the maintenance of all the sections and new equipment was coming regularly from the United States.

After the signing of the Armistice all the sections in the field, except the two Flash Sections with the 3rd Army which was to advance towards the Rhine, were ordered to collect their material and take in their lines and return to Battalion Headquarters.
shipment to the United States.

At the present writing the Battalion is awaiting orders for return to the United States.

All materials other than technical in the depot were returned to the general depots or the salvage dumps and all purely technical material of use for sound or flash ranging only was boxed ready for

B. ORGANIZATION.

G. H. Q. General Orders No. 8 American E. F., placed the Ranging Service in the Topographic Division of the Intelligence Section of the General Staff. The Intelligence Regulations, Article 82, state "Observation (Flash) and Sound Ranging Sections, while administered and located by the officers of the Engineer Corps, are under the immediate orders of the Artillery Information Officer of the Corps in all that pertains to the tactical use and employment of such sections." The technical supervision both as regards training and the supply of technical supplies which by the orders and regulations as vested in the Engineers has been performed by an Engineer officer attached to the Chief of the Topographical Division of the Intelligence Section of the General Staff at General Headquarters.

The duties of this officer have been to act as technical advisor to the Chief of G-2-C in matters pertaining to the Ranging Service and to act for him in supervising the training of officers and enlisted men at the schools in arranging for the construction of technical equipment in Europe and the United States, in the maintenance and proper functioning of a depot for technical supplies needed by the schools and the sections operating at the front, to inspect at frequent intervals the front line sections, to insure uniformity in technical operations and to insure that the available front line sections are employed to the best advantage with reference to future operations.

The Engineer officer at G. H. Q. did not require especial clerical or other assistance in view of the fact that those of G-2-C were at his disposal.

Schools and Depot.

School. The organization at the School was one Captain in charge of instruction in both the Sound and the Flash Ranging, one Lieutenant instructor in Flash Ranging and two Lieutenants instructing in Sound Ranging and a total of seventeen non-commissioned instructors and assistants.

While undergoing instruction at the school, the officers of a Company were relieved of all Company duties and the men of all post duties in order that the time of instruction might be reduced as much as possible. In order to effect this a relatively large personnel (40) was kept at the school, including labor detail, cooks, chauffeurs, orderlies, etc.

Instructors and others of the school detachment were frequently changed for the purpose of keeping, at all times, the school in close touch with the working of the sections at the front.

Because of the fact that sections at the front were broken up into groups, a relatively large number of cooks were needed per section. To meet this need, a school for cooks was maintained at the Ranging School in which some of the men unsuited for instruction in the more technical training were taught by the Company cooks.

In the appendix to this report is shown a sample Roster of the School of the date of October 29, 1918. At this time one Company was undergoing instruction and short courses were being given to groups of Artillery officers.

Depot. For the handling of all special technical supplies, a small depot detachment was provided. It consisted of 18 men in charge of a Second Lieutenant. In addition to the usual clerical and messenger work, this detachment inspected, tested and repaired apparatus arriving from America or returned for slight repairs from the front-line sections. It thus performed some of the functions of a laboratory and shop which it was planned to install as soon as the growing needs of the sections should render it necessary.

Organization With An Army.

The Tables of Organization No. 231, a copy of which is included in the appendix to this report, shows the personnel of a five Company Battalion. The large allowance of Commissioned officers per Company is due to the fact that each Company is divided into four sections and each section requires from three to four commissioned officers because of the varied technical duties to be performed at these sections (Computations, Instruments, Lines of Communication, Observatories, etc.).

The allowance for Battalion Headquarters is 4 officers and 29 enlisted men. A small reserve of technical equipment and what reserve transportation there may be is kept at Battalion Headquarters.

On quiet fronts it is possible to form from the Company two Sound Ranging Sections (55 men each) and two Flash Ranging Sections (70 men each).

On active fronts as many as 80 men may be needed for a Sound Ranging Section and 90 for a Flash Ranging Section. In this case

a Company could furnish two Sound Sections and one Flash Section.

At Company Headquarters, which may also be the headquarters of one of the sections, any reserve of men and material which it may be possible to build up is kept.

Criticism of Organization as Regards Personnel.

The personnel allotted to the School in the American E. F. is probably too large for any condition other than that of great and rapid growth of the organization. For the case where only replacements need to be trained, a much smaller teaching force would suffice. In this case there should be an officer whose duty it is to carefully pick the replacements so that only likely men should be selected for training. The conditions existing in the American E. F. were abnormal. Companies arriving from the United States were put as units in the School. Many of the men had not been picked with reference to the work they were to do and a great deal of shifting of men to other tasks had to be made which involved duplication of instruction. A list of qualifications of enlisted men which should be consulted in forming a Company or in picking replacements is included in the appendix to this report. The personnel allotted to the Depot is nearly adequate for a five Company Battalion. It should be augmented by a few skilled mechanics to work in a machine shop which should be provided for experimental and repair work.

The personnel allotted to the Battalion Headquarters should be increased as regards enlisted men, who should be trained so as to serve as a small reserve in case of emergency to meet the need of either a Sound or a Flash Section.

Of the two Captains allowed to Battalion Headquarters, one should be in general supervision of the Sound Ranging and the other of the Flash Ranging in the Army Area, particularly if the Battalion is formed to the maximum strength of five companies. The division of the Company into both Sound and Flash Sections has not proved wholly satisfactory nor with the two Captains at Battalion Headquarters does the need of a Captain of a mixed Company seem very clear.

It would probably prove more satisfactory if one Company were to furnish three Flash Ranging Sections, another Company were to furnish three (or four) Sound Ranging Sections, the sec-

tions themselves to be under the charge of a 1st Lieutenant and the Captain of the Company stationed at Battalion Headquarters or other suitable central position with the duty of attending to the Company business and general and constant personal supervision of his sections. In this case, one of the two Captains allowed for a Battalion Headquarters could be dispensed with.

It should be noted that unless the plan proposed above is adopted at the outset the natural tendency will be to organize as was the case in the A. E. F. The chief difficulty with this organization proved to be this: The Captain was either a Sound Ranger or a Flash Ranger and his chief interests were with either the one or the other service (or such was supposed by his subordinates to be the case). The Company paper work, the pay of the men, etc., was difficult to manage and will be difficult in any organization in which the section itself is not the unit.

Further criticisms of the Section organization are contained in the Section Commander's reports in the Appendix to this repoort.

C. EQUIPMENT.

The equipment of a Battalion of 5 companies (maximum), consists of three parts. First Transportation, 2nd Individual Equipment, and 3rd Technical and other supplies. Of these, the 1st is specified in Table 231 already mentioned as contained in the appendix to this report. This table was drawn up with the requirements of position warfare in mind and should be modified in light of what has been learned during the more mobile warfare of the late summer and autumn of 1918. With this in mind, another table has been drawn up (though it has not been authorized by G-1) which sets forth what would be regarded as an adequate amount of transportation for a Battalion under mobile warfare conditions.

It should be noted that estimates of transportation for war in Europe where good roads are the rule, and where horse-drawn transportation was even more difficult to obtain than motor-drawn, might need to be fundamentally modified for war in the United States.

In the (unauthorized) table mentioned above is listed also personal equipment adequate for the men in position warfare and lastly technical supplies. This last portion of the table is practically an inventory of what has actually been used during the eight months the American sections were in the field and should

prove a valuable guide if sections of this character have again to be put in the field.

Technical Equipment: Flash Ranging.

Optical. The French instruments furnished by the *Section d'Optique* of the *Service Geographique de l'Armee* have been exclusively used in the Flash Ranging Sections of the American E. F. From the optical point of view only are these instruments satisfactory or suited to the purposes to which they have been put. From the mechanical point of view they are highly unsatisfactory. This matter has been the subject of a special report by Lieutenant Colonel Trowbridge to the Chief of Engineers, Washington, D. C., with the object of securing a more suitable instrument had the war continued. It is a purely technical matter which would be out of place in a report of this sort but it is thought to be in place to emphasize the great importance of developing in peace times an instrument, or instruments, which will meet the needs of the Flash Ranging Service.

Electrical. French Flash and Buzzer boards were for the most part used in the American Sections. These were on the whole satisfactory though they were bulkier than was necessary. An English Flash and Buzzer board was also used and the first American Flash and Buzzer board to arrive in France was also given a trial under front-line conditions. Any one of these various boards works satisfactorily, though the advantage is decidedly with the telephone accessories of standard American make.

Sound Ranging. The French T.M. apparatus was used for instruction purposes in the school, since it was thought that the American sections first formed might have to operate French installations before English or American apparatus was available. This proved not to be necessary.

Two different sets of American modifications of the French T.M. apparatus were sent to France by the Chief of Engineers for experimental trial. These were constructed by the National Bureau of Standards, Washington, D. C. The first of these sets was accompanied by employes of the B. of S. Commissioned in the Engineers. The senior of these officers, Captain Weibel, was killed at the front before the apparatus which accompanied him was delivered at the Ranging Depot. The junior of these officers, Lieutenant Fecht, carried out a test of the apparatus at the School and reported it

as of insufficient sensitivity for practical use at the front. Later the design of this apparatus was considerably modified and a new set of apparatus was sent to France accompanied by two civilian employes of the B. of S. The apparatus arrived after the signing of the Armistice and for this reason could not be subjected to a front-line test. It was tested, however, at the School in competition with the standard apparatus as regards its special suitability for use in a mobile Sound Ranging section. In this respect it compared favorably with the standard apparatus and as regards sensitivity it was superior. The test was, however, by no means exhaustive enough in character to warrant any conclusions as to whether or not the B. of S. apparatus would prove as generally satisfactory as the Standard apparatus. This matter would be a proper subject of inquiry in time of peace, as it was impossible to properly study the matter in France during the war. One other experimental system was sent from the United States to France and was tested at the School and found unsuitable for use in the field, though it showed great possibilities in the matter of sensitiveness. The so-called modified Defour apparatus should be developed further in the light of what has been learned practically during the last year if it is decided to continue development work on Sound Ranging apparatus in the United States after the war.

The Sound Ranging apparatus actually used in the field by the American sections was that known as the Bull-Tucker system. The apparatus installed at the different sections differed slightly in minor details, but was on the whole well standardized and performed in a manner wholly satisfactory. The wisdom of the choice a year ago of this type of apparatus has been proven beyond all question. Thanks to the hearty cöoperation of Colonel Jack, Lieutenant Colonel Winterbotham and Major Bragg of the British "Maps" sufficient apparatus and supplies were always at the disposal of the American Sound Ranging service until satisfactory apparatus of the same character began to arrive from the United States.

Apart from the instruments used in both the Sound and Flash Ranging service there were a large amount of other equipment and supplies of a highly technical nature. These were secured partly by purchase through the Engineer Purchasing Officer in France and partly by requisition from America through the Chief Engineer, American E. F. These were always to be had, when needed, through these channels. In fact no Sound or Flash section was

ever out of action through lack of materials from the date on which it was tactically possible to inaugurate the service to the date on which hostilities ceased.

Criticism of Equipment.

A criticism from a technical point of view would be out of place in the body of this report and forms the subject of a short report in the Appendix.

In general it should be pointed out that such unsatisfactory features as there were about the equipment, and these were on the whole not numerous, could easily have been remedied had it been possible to install at an early date a machine repair shop in connection with the technical depot. The plans which had early been made to provide such a shop were delayed for various reasons, such as the delay in shipping overseas of special troops, the difficulty of procuring tools, stock and skilled mechanics in France.

As already pointed out earlier in this report much labor and expense could have been saved had it been possible to arrange for the construction of, or minor changes to, the more technical part of the equipment in France. A machine shop for repairs and modifications of finished apparatus was constructed in July, 1918, and requisition was made for the necessary tools, but a very small portion of the equipment was obtainable in France so it was recommended that a detachment of eight machinists already engaged in construction work for the Ranging Service in America be ordered abroad with all their tools and equipment. At the time hostilities ceased this detachment was on the point of embarkation.

It should be noted that *all* of the Sound Ranging and a large part of the Flash Ranging apparatus was developed, whether by the French, British or ourselves, *during* the progress of the war and consequently under conditions that rendered inevitable a lack of standardization of equipment and the employment of makeshifts in place of more suitable material. Many valuable lessons were learned by certain of the personnel of the sections and the knowledge so gained should be made use of in standardizing the bulk of the apparatus which is sent to the United States. If this be done, samples of each of the types as designed should be kept for historical purposes.

D. OPERATION.

A report under this heading can best be given in the form of appendices containing all printed and typewritten matter describing the scope of the work of the Sound and Flash Ranging, *i. e.*, Reports of officers in charge of sections, school and depot. These appendices are grouped under the sub-headings School and Depot, Sound Ranging Sections, Flash Ranging Sections and Miscellaneous.

School. The number of students who went through the A. E. F. Ranging School is of course approximately the same as the number constituting the 2nd Battalion of the 29th Engineers—that is, about a thousand men and some sixty officers. The numbers of enlisted men entering the school per month were as follows: February, 50; March, 109; April, 67; May, 40; June, 40; July, 129; August, 165; September, 261; October, 283.

In addition to these numbers receiving full instructions, there were on the average about 600 officers per month who were given a general lecture on Sound and Flash Ranging at the school. There were for the most part Artillery officers. During the latter part of November and the first part of December, 1918, three hundred students of the Army Candidates School were given two days instruction each at the Ranging School. In addition to the lecture just enumerated, a number of special lectures were given at irregular intervals to visiting officers and officers from the General Staff College.

As will be seen by the outline of the courses offered, which are included in the appendix to this section of this report, all students were not put through the same course of training. On their entry into the school, the men were classified into groups according to their qualifications as follows: Linesmen, Observers, Instrument men, Computers, Draftsmen, Chauffeurs, and Unskilled. The instruction in linemen work did not need to be duplicated, since it could cover the needs of both the Sound and the Flash sections. It is difficult to train satisfactorily in the rear areas the men for the observation posts of both the Sound and the Flash Ranging. All that can be done is to carefully pick the right type of men and give them practice in the rapid and accurate observation of transient flashes, smoke puffs, etc., under working conditions which approximate those existing at the front. For this purpose any experimental installation for both the Sound and Flash Instruction was

made at the school and the men were drilled in the manning of the observation posts by day and night under conditions rendered as near as possible similar to practical working conditions. The training of observers at the school should last only long enough to insure the picking of the right type of man and the rejection of the unfit and then the observers should finish their instruction at a well conducted front line section.

A certain amount of overlapping of the special courses was provided for so that each man might have an intelligent understanding of the duties of the other men in the section. The men enlisted as unskilled were used as helpers and were given some general instruction in map reading, linesmens work, etc. The last week of the course (of 3 to 4 weeks) was devoted to training *as a section* since the conditions existing in the A. E. F. required the forming of sections at the school with but a small nucleus of experienced men from sections which had already been operating at the front. It is doubtful whether training carried on in the rear areas can be made entirely to satisfy the requirements of the section commanders at the front, even though a conscientious effort be made to keep close liaison between the officers of the School and the front line sections. The difficulties of close liaison were realized and every effort was made to secure a frequent interchange of officers and selected enlisted men between the front line sections and the school. This was at all times and, particularly at first, very difficult to carry out owing to the scarcity of suitable men at the front who could be spared for work at the school. However, in a seven months period two different officers were at the school in general charge of the work and nine different officers acted as assistants in teaching. None of these officers were removed from the school because of their work having been in the least unsatisfactory, but only because there was more pressing need for their services at the front.

The operations of the school can be divided roughly into two periods: January 6 to July 20, 1918, and July 20 to November 11, 1918. During the first period of five months only Company B of the 29th Engineers (and Replacements) was trained. During that time no definite schedule of training could be carried out, as the men were available for school duties only at odd times as they had to be used for all sorts of duties about the grounds of the Army Engineer School at Fort St. Menge. During the second period definite schedules of instruction were carried out according to

prearranged plans. The men were put through the school in about a month's time, including practice in operating as a mobile section, and each man when he went to the front carried with him a record card showing his performance at the school so that he might be assigned to work at the front with due regard to his past performances at the school.

On the whole, the training of the enlisted men was more satisfactory than that of the officers. This was particularly the case in the Sound Ranging, which is the more technical of the two services. It is not possible to so standardize procedures that the necessity for making at times difficult technical decisions shall be removed from the officers in charge and it is therefore highly important to put sections in charge of officers who have scientific habits of mind based on extended experience in weighing scientific evidence. It is very difficult to find these qualities combined with executive ability and yet a combination of these qualities is desirable in a good section commander.

Whether a section is good or poor depends very largely on whether or not it is in charge of a very well poised officer. In time of peace doubtless much could be done with pliable material by instruction at a school run by a teacher who himself is of the type described above. In time of war, however, the period of instruction is necessarily reduced and sections have to be put in charge of officers who lack a scientific habit of mind and the accuracy of the work of the section suffers in consequence even though, judged from other standards, the section may be functioning well.

The matter of the selection and subsequent training of officers is an extremely important one and presents far greater difficulties than the selection and training of the enlisted men. To avoid having to again struggle with these difficulties in the case of another war a number of the officers who have shown the proper qualifications for the ranging service in this war should be retained as reserve officers to serve, if called to active duty, with whatever may be kept as a skeleton organization during peace time.

Depot. The depot for technical supplies was situated at Langres in charge of a lieutenant who had under him a detail of from fifteen to twenty men. The depot was housed in a set of four barracks conveniently situated with reference to a high road and there was in addition storage space of about 2,000 square feet near the railroad where the main supply of the special wire used in Sound

Ranging was stored. Exclusive of this latter storage space, the floor space found adequate for the purposes of a five-company battalion was 3,700 square feet.

One building was devoted to small technical supplies and one to general supplies which, until the time of the battalion organization was formed, it was necessary to carry at the special depot. Ultimately, it would have been possible to do away entirely with the carrying of general supplies at the technical depot. The two other buildings contained an office, a drafting room where a certain portion of the work, which would otherwise have to be done at the sections, was attended to under good working conditions, a testing room where all apparatus was tested before it was shipped to the front, a carpenter shop and shipping room. As stated earlier in this report, a machine shop building was provided but it had not yet been equipped with tools nor had the officer and machinists selected for the work of research and construction arrived from the United States at the time the armistice was signed.

A table of expendable supplies handled by the depot during the six months period ending October, 1918, is contained in the appendix to this section of this report. This table is reduced to the basis of quantities per section per month and should prove of considerable value to any future supply officer.

A copy of the final report of Lieut. Maurice Pate is also included in the appendix to Section E of this report. This officer deserves the highest commendation for the systematic and efficient handling of the depot. He combined a very good technical knowledge with considerable experience in supply work gained through association with the Commission for Relief in Belgium before the entry of the United States into the war. On the whole the work of the depot was very satisfactory and very close touch was kept between it and the front line sections and there was good mutual understanding of needs and facilities.

Sound Ranging Sections. The value to the Army of the work of the Ranging Sections depends on the reliability of the information gathered and the amount of such information compared to the total amount obtained from all available sources.

With regard to the reliability of the information obtained by the American Sound Ranging Sections attention is called to a very complete report on this subject prepared by Capt. C. B. Bazzoni, Engineers, compiled from records and surveys of German

gun positions in the St. Mihiel Salient. A printed copy of this report with maps and diagrams is included in the appendix to this report. One result of ths study is that while individual determinations of an enemy gun position may be, under unfavorable circumstances, as much as one hundred meters in error, the average of from five to ten separate determinations made on different days is of an extremely high degree of accuracy, in many cases of the order of ten meters. It shows further that the system on which reports have been made errs on the side of conservatism—that is, a location estimated and reported as poor is usually fair and a fair is a good. It further brings out the fact that lists of active batteries compiled from Sound Ranging data are extremely reliable as regards the real activity of the batteries in question. The A. I. S. lists, which are based on information from various sources such as Airplanes, Balloons, Flash Ranging, Sound Ranging, etc., will always contain many locations which subsequent examination will prove to have been enemy works other than battery positions (dugouts, etc.), or battery positions not actually occupied. For this reason the A. I. S. lists, while they are undoubtedly incomplete because they can hardly be expected to contain *all* the enemy batteries are, in addition, liable to be incorrect in that they contain locations not corresponding to active batteries: For example, if there are 100 actual active enemy batteries in a certain sector, the A. I. S. list might contain, say, 80, but of these 10 might not be active or possibly not battery positions at all. In this case, as regards identification, the A. I. S. list would be 70 per cent correct (not 80 per cent). If, for example, the Sound Ranging Sections in the sector reported (say) 50 different locations, it would have reported one-half. It would have appeared to have contributed 5/8 of the Artillery information and it would have actually contributed 5/7 of the reliable information.

This example is given to show the difficulty of appraising numerically the relative worth of the Sound (or the Flash) Ranging in the Army Artillery Intelligence Service. With this example in mind the following data will give some idea of the work of the Sound Ranging Sections in the sector of the 4th American Corps.

In the period from September 9th to September 30th, 1918, there were as sources of information three Sound Ranging Sections, two American and three French Flash Ranging Sections, Aviation, Balloons and miscellaneous. In this period occurred the St. Mihiel

offensive and the Sound Ranging Sections were practically out of action for one week except for very short periods. The total number of separate battery locations listed by the A. I. S. of the 4th Corps for the whole period of three weeks was 425. Of these the two American Flash Sections reported 34 per cent, the three French Flash Sections 16 per cent, the three American Sound Sections 21 per cent. On the same front, in the period from October 1st to October 15th, the total number of separate locations was 392 and the percentages were: From three American F. R. S. 38 per cent, two French F. R. S. 8 per cent, three American S. R. S. 56 per cent.

In the first of these periods, the weather conditions were good, in the latter period they were on the whole unfavorable, for Flash Ranging. During the last six weeks of the war the three American Sound Ranging Sections just mentioned were credited with about 65 per cent of the locations in the area. As indicative of the variation from month to month of the percentages of locations credited to a section in a quiet sector the following figures are given: May, 40 per cent; June, 60 per cent; July, 45 per cent. The weather conditions during this period were relatively more favorable for visual observation than for Sound Ranging.

The very meager data which exists on the performance of the German Sections are of interest in this connection. In May, 1918, one S. R. S. got 10 per cent, two F. R. S. got 45 per cent and the Air Service 45 per cent of the Artillery information in the XIV German Army Corps. In July the numbers were respectively 10, 63 and 27 per cent. The German Sound Ranging Apparatus was apparently very crude and the methods very slow, judged from our standards. The Flash Ranging was apparently very good.

It should be noted, as pointed out above, that these percentages are merely indications since they cannot be formed on an actual knowledge of the number of active enemy batteries. The relative value of the Ranging to the other sources of information, while it is a fair statement for the actual conditions at the time, takes no account of the number of men and the resources employed by the different agencies in gathering the information. Sufficient data to make such a comparison are not available. The upshot of the whole matter of efficiency seems to be that a very creditable per cent of all the locations made are credited to the Sound Ranging Sections and that in the future more reliance must be placed in compiling

the A. I. S. lists on locations repeatedly made by S. R. S. even though such locations are not confirmed by other sources of information. This practice would reduce the number of the enemy batteries listed by the A. I. S. without serious omissions and might occasionally serve to prevent the omission of important batteries.

There is one other point in connection with efficiency which should be made. An examination of the records of the sections shows that only about 10 per cent of the films taken result in locations of enemy guns. In all the period and in all of the sections this percentage is about the same. The value of the materials wasted is insignificant and the question of efficiency is not raised on this account but rather because the figures may point the way for an increased general information efficiency. Some, and possibly a large number, of the wasted films come from the observers at the advanced posts starting the apparatus when they hear reports which do not come from enemy guns; others come from the inability of the computers to correctly interpret the records—either due to carelessness, lack of sufficient training or, more probably, because of the uncertainty of the wind and temperature conditions. By training and by research in peace times it should be possible to materially reduce the percentage of wasted record films and so increase efficiency generally.

Flash Ranging Sections. The battle conditions under which the American Flash Ranging Sections have worked have been very unfavorable for the collection of data on which to judge the accuracy and efficiency of this work.

The first section in the field, F. R. S. No. 1, took part in the operations around Chateau Thierry and on the Vesle, later in the St. Mihiel Drive and finally in the Argonne. Of the work of this section, the following is said in Bulletin No. 9, Office of the Chief of Artillery, G. H. Q., "The work of the F. R. S. during the entire advance has been excellent. In spite of lack of transportation and continual movement it has given good information. During the attack yesterday, men went forward with the infantry so as to find good observation posts." Because of the continual movement of this section it has been impossible to gather data as to the accuracy obtained by this very experienced section; the following data will give an idea of the efficiency of the section:

From—	Period.	Battery Locations.			
		F.R.S.	S.R.S.	Balloons	Aviation.
July 13-17	Active Stabilization	22	22	0	0
July 18-August 4.	Advance	46	4	30	77
August 5-9.......	Stabilization	34	6	13	15

These figures are characteristic. During preparations for an advance, both the Sound and the Flash Sections are very useful and important sources of information. During rapid advance the Sound Ranging does not get into action as often or as soon as the Flash. In this period the bulk of the information comes from the Air Service.

The data given above under the discussion of the Sound Ranging Sections illustrate the relative importance of S. R. S. and F. R. S. in the operations in the St. Mihiel sector.

As regards the accuracy of the Flash Ranging locations in this sector where an accurate survey was possible the following can be said: 33 per cent of the batteries were located to within 50 meters, 29 per cent to within 100 meters, 24 per cent to within 150 meters and 14 per cent to within 200 meters. That this showing is not better is in large measure due to the fact that the only available instruments were unsuited to the purpose of accurate Flash Ranging.

Miscellaneous.

Because of the organization in the A. E. F. of the Ranging with Survey and Printing certain facilities of the latter were available for the former. Very competent surveyors were available and their services were called on to some, though it now appears not to a sufficient, extent. In practice in the field, surveys were frequently made by the members of the ranging sections in order to save time. This is as it should be but unless highly trained surveyors do this work it is likely to be of insufficient accuracy for obtaining the best results and positions should be checked up by a topographic party. This was not always done.

In position warfare the practice should be to have a survey party of the Army as part of its routine work check up and correct the location of all observation posts and microphone emplacements on the Army front. For the case of more mobile warfare a survey by members of the ranging sections must suffice: To insure that

this shall not be too inaccurate a special training in survey methods should be given in the school for officers and provision should be made that at least one officer of the section should be well trained in survey work. For position warfare panoramic sketches should be prepared for all the observation posts, as they are of the greatest assistance to the observers. These were prepared from photographs taken by a small photographic section under direction of an officer of G-2-C. In semi-mobile warfare this would have been impracticable.

For instruction at the School and for choosing suitable observation posts and microphone emplacements for reserve or advance positions, the relief models constructed by G-2-C proved very useful. Rapid and sufficiently accurate studies of visibility were early made with the help of these models. For semi-mobile warfare this use will be restricted to illustration in training.

With a body of enthusiastic and energetic officers and men engaged in rather special technical work there will be always many suggestions of improvements of method and apparatus coming in from the Sections, School and Depot. This very healthy interest and enthusiasm must be encouraged by providing facilities for the construction of the models and apparatus necessary for the trying out of the most promising of the new ideas. At the same time careful supervision of methods and apparatus must be maintained in order to prevent a lot of minor modifications from destroying the standardization of apparatus and methods without any compensating advantages. In the A. E. F. a research shop was planned for in connection with the technical depot though the facilities available for the purpose were not adequate at the time of the signing of the Armistice. Actually a number of graphical calculation devices were prepared and printed, a few minor changes were made in apparatus constructed in the United States, some French commercial electrical apparatus was adapted for a special use and some comparative tests of new apparatus or new modifications of the standard apparatus were made. It would have been imperative to have strengthened this department very materially had the war lasted longer.

Reorganization.

In the event that at some future date it shall be necessary to organize ranging sections it is highly desirable that there be kept

in the permanent establishment of the United States Army a small skeleton organization which may be filled up in time of war. If this be done the greatest single obstacle to the speedy organization and functioning of the ranging sections encountered in this war may be avoided.

Whether or not such a skeleton organization in peace time should be under the Corps of Engineers or under the Artillery is a matter which should be discussed on broader lines than any taken in this report. In either case the skeleton organization should be stationed at an Artillery firing field where practice in ranging both the field pieces and the moderate caliber howitzers may be had. This is unquestionably preferable to a location at an Ordnance Proving ground since it is more important that the sections be trained with the arm with which they work in war than it is that they be trained at a place where there is more and a greater variety of firing. It should be noted that this arrangement is also advantageous for the Artillery. In general it is quite as important for the Artillery to receive training in the employment of the ranging sections as it is for the ranging sections to get their training in areas where guns are being fired. The closest possible coöperation between Artillery and the ranging sections should be insured in any rational plan of peace time training.

The skeleton organization of peace times should maintain four activities, viz: Training, Supply, Research, Sound and Flash Ranging operations with the Artillery. These correspond to the main activities of the ranging service in the present war. In the matter of training it would be well to follow closely at first the course of training which has been followed in the A. E. F. and which is outlined in the appendix to section D of this report. This course is modeled on French and British practice during the present war, modified, where necessary, to meet the especial conditions existing in the A. E. F., which were the rapid training of relatively large numbers of men. A course of training in peace time will probably differ from this in this respect that the training will be more leisurely and broader in the fundamentals of geometry, trigonometry and electricity. In the matter of supply it is highly important that men be trained to be thoroughly conversant with the workings of the general supply system of the Army and the sources of quick emergency supply of the many technical supplies needed in ranging which are not at present listed among the regular army supplies.

The apparatus for ranging which is returned to the United States from France should be standardized so as to conform to one satisfactory self contained model ready for setting up in the field and packed according to a definite well understood plan. Complete sets of such apparatus should be kept in reserve. The men should be trained in the use of apparatus identical with that held in this reserve.

Research should be carried on with the view of improving the instruments used but such research should not be allowed to result in trifling minor changes which would result in destroying the standardization of the apparatus. Research should not be carried out by those not in close touch with the practical matters which come only from a knowledge of field conditions. The tendency of research during the present war has been towards a development of too elaborate apparatus in the case of Sound Ranging. This has been on the whole true in both the English service and that of the A. E. F. The cause of this is the same in both Services, though the effects have been more pronounced in the American than in the English case, *i. e.*, the carrying out of suggested changes and improvements at too great a distance from those engaged in operating under field conditions.

In the matter of the operation of Sound and Flash sections with the Artillery care should be exercised to guard against the formation of too permanent installations. The sections should be made to occupy a variety of positions and the necessity of mobility should be constantly kept in mind. Valuable suggestions with regard to this are to be found in a memorandum on mobility by Captain C. B. Bazzoni, included in the appendix.

Great mobility for the Sound Ranging is not needed since all that is necessary is that the sections shall be in place when the enemy heavy artillery is occupying more or less fixed positions. However, ease of mobility is much to be desired and a somewhat greater degree of mobility than has been attained in this war is also desirable. At present it seems reasonable to seek a solution in the direction of retaining as much as possible of the present equipment and to use transformers to permit of reducing the weight of wire needed by a section. Increased mobility for the already very mobile Flash Ranging is highly desirable and may be in part achieved with greater transport allowance and might be very

materially increased if wireless can be substituted for wire communication between the central and the outposts.

There is one side to the Flash Ranging which has not been sufficiently developed by the Allies during this war, though it would appear that it has been considerably developed by the enemy, and which should receive very careful attention in peace time. Ranging on invisible targets by the method of High Bursts.

Work along four different lines has been begun by the Allies as follows: (a) Very long range Artillery adjustment known as the Systeme Telemetrique. (b) Method of the Tangent Reticule. (c) Air burst ranging by the method of the False Angle of Site and (d) by the method of burst on the true trajectory.

Methods (a) and (b) have been experimented with by the Artillery and methods (c) and (d) by the Flash Ranging Sections of the French, British and American Armies. With regard to the last two methods it appears that method (c) is at the present time the more promising.

The subject of High Burst Ranging has been much to the fore during the last months and has been the subject of several conferences between the officers charged with the supervisions of ranging in the various Allied Armies. A separate folder containing all available data is prepared to accompany the copy of this report which goes to the Chief of Engineers.

It should be pointed out, however, in the body of this report that it is the opinion of all who have been connected with the Flash Ranging in the A. E. F. that High Burst Ranging should be developed; that a study should be promptly made to determine which of the various methods mentioned above is the most suitable for adoption and that suitable optical instruments be constructed and Artillery observers be trained in the use of them on the Artillery firing fields. There will doubtless be considerable ammunition available for practice firing of the Artillery in the period immediately following the close of this war. It should be noted that during this period a technique of High Burst Ranging could be most easily developed and further that important data on exterior ballistics could be gathered by a competent Flash Ranging Section.

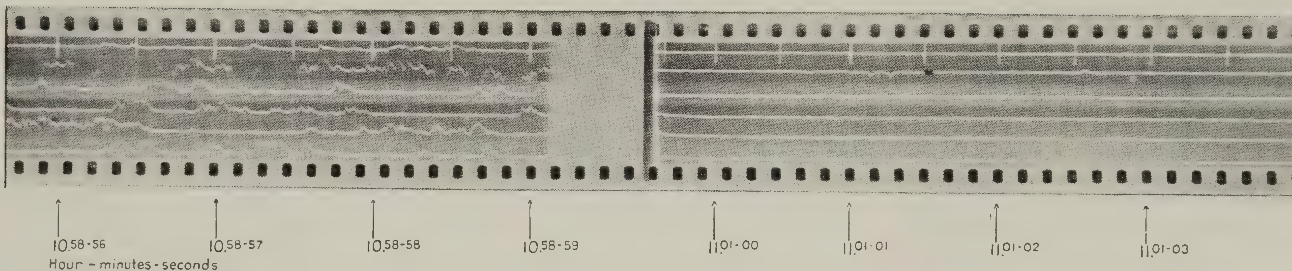
In the reorganization of Ranging on a peace time basis any tendency to follow too slavishly practices which have worked well in Europe must be guarded against. It is very questionable whether position warfare of so great stability as that characterizing the

campaigns of 1915, 1916 and 1917 in Europe is likely to be fought on the American continent. Sound Ranging in its present state is a product of such a warfare of position, though it is perfectly capable of sufficient mobility. Both Sound and Flash Ranging as practiced in this war, while dependent on the existence of accurate maps, are no more so than is the Artillery which they serve. However, it appears in the light of present experience that in a campaign in a country less well mapped than France relatively more use would be made of the sections for *ranging* on a target that has just fired than for the *location* of targets or for the ranging on a map point. In this case the effect of map inaccuracies would be minimized and temperature and wind corrections for Sound Ranging rendered unnecessary and the whole installation might be made less elaborate and more mobile.

Graphical record of the
End of the War

One minute before the hour.
All guns firing

One minute after the hour.
All guns silent



November 11, 1918

Last record, by Sound Ranging, of Artillery activity on American front near the river Moselle

Broken character of records here indicate great artillery activity - mostly American – Lack of irregularities here indicate almost complete cessation of firing

Records of this character are used not only to indicate activity as in this case but in order to locate the positions of the enemy guns firing, thus targets and the caliber of the enemy guns - Sound Ranging Sections similar to the one which took this record are part of the Army Intelligence and are maintained in sufficient numbers to cover the entire front - They are operated by the Engineers.

ACCURACY OF S. R. S. AND F. R. S. LOCATIONS.
PERIOD SUBSEQUENT TO ST. MIHIEL OFFENSIVE.[1]

In appraising the services rendered by the Flash and Sound Ranging Battalion of the American E. F., the nature of the work and the character of the sectors in which the various sections operated must be kept in mind. The Sound Rangers were first in the field, they went into a sector in front of Toul and with but one exception of brief duration all their work was carried on in the same region. They had therefore every opportunity for the preservation of systematic records. This opportunity was made the most of as the full and interesting data collected bear witness. The Toul sector, however, was not of great strategic importance during the period under consideration, and was never the scene of any considerable military operation up to the time of the St. Mihiel drive; the service rendered by the Sound Rangers was therefore rather characterised by routine observation excellently executed than by any single achievement directly connected with the outcome of the war.

The service of the Flash Rangers was of a different character. Late in getting an opportunity in the field, the first organized Section did not reach the sector in front of Toul until the end of April and even then its presence was rather tolerated than required, the ground being covered by a French Ranging Section. It was only during the first ten days of June that Flash Ranging Section No. 1 was ordered directly at the personal instigation of the C. in C. himself to the neighborhood of Chateau Thierry. At this crisis of the war the 2d Division (being entirely destitute of aerial observation) found itself without means of locating the enemy's guns. The services of the Flash Rangers proved of great value to our Artillery from the first. Later the section followed close upon our infantry in its advance to the Vesle.

When it is remembered that the operations of our troops on the Marne between June and August determined the victorious outcome of this war, and when account is taken of the important services rendered by Flash Ranging during the most critical part

[1]Prepared by G-2-C, G. H. Q., A. E. F., January, 1919.

of this period, it may well be considered that Flash Section No. 1 alone has justified the labor spent on the whole Ranging Service.

Before the attack on the St. Mihiel salient, F. R. S. No. 1 was ordered into this sector, where F. R. S. No. 2 had been previously established for a short period; these two Sections participated in the drive. In October, F. R. S. No. 1 was moved into the 1st Army Area. F. R. S. Nos. 3 and 4 were put in operation for a relatively short time only.

It is obvious therefore that the history of Flash Ranging has been one of excitement and change. The contributions have been most important but the battle conditions under which Flash Ranging has worked have been unfavorable for the collection of data. The results which can be tabulated in no way do justice to the importance of the service.

The data on the accuracy of Sound Ranging locations made prior to the St. Mihiel offensive which have been published by G-2-C, G. H. Q., were collected under exceptionally favorable conditions. The front had been stable for a long period and the Sound Ranging Sections had been in place for a considerable period of time and the officers and men were thoroughly familiar with the general distribution of the enemy artillery opposite to them. After the advance a careful survey by G-2-C of the 2d Army was carried out and a systematic comparison of the records of the locations reported by the Sections with the result of the survey was made.

It was impossible to carry out a similar investigation in the same area to determine the accuracy of the Flash Ranging Sections for the reason that, prior to the offensive, American Flash Ranging Sections had not worked continuously in this region as it was not favorable for visual observation and as the American Flash Ranging Sections were not in the field as early as the Sound Ranging Sections.

After the St. Mihiel offensive the American positions were more favorable for visual observation and from that time until the armistice both Sound and Flash Sections were working on the 2d Army front. During this period a great many locations were made and after the armistice a hasty survey of the enemy battery positions was undertaken in part by G-2-C and in part by the Sections themselves, with the object of preparing a report on the accuracy of the ranging operations similar to that which had been made of the operations prior to the offensive. This report is by no means as complete as the former for a variety of reasons. First: The 1st bat-

talion of the 74th Engineers, which comprised all the ranging troops in France, was ordered to prepare to return to the United States and the survey and completion of data were hurried on that account. Second: It was evident that the estimation of accuracy of the individual locations was less reliable than had been the case on the more stable front. Third: The enemy was found to have been using many roving pieces and firing from a great number of transient positions so that it became difficult in making up a report of the operations to correlate the various locations with the surveyed positions.

For these reasons the data are not here presented in the same form which was used in the presentation of the previous data. The importance of the report did not seem to warrant this since it is not always possible to draw clear conclusions from the data. Those which may safely be drawn in general are these: For certain regions, where it was evident from an inspection of the ground that an enemy battery had been active for a long period, the ranging locations were well distributed around the battery position—it would have been misleading even in these cases to *guarantee* either a single Sound or a Flash location to within one hundred meters—however, in these cases there were generally so many independent Sound Ranging locations that it would have been safe to guarantee the average of more than five locations, without taking account of their estimated relative accuracy, to within about fifty meters. The numbers of separate locations of a battery by Flash Ranging were in general not sufficient to give a mean value of greatly better value than that of the individual locations. Many of the individual Flash Ranging locations are of a high order of accuracy—so accurate in fact that one is surprised at the apparent great inaccuracy of certain others unless one can explain them on the hypothesis of temporarily occupied portions, at least in those cases where the locations are found in open fields on high ground. Inaccuracies of location by Flash Ranging of defiladed portions are of course to be expected. Of the locations by Flash Ranging about one-third are accurate to within 50 meters, another third are accurate to within 100 meters. The positions of the batteries found by survey are shown as crosses on the accompanying maps. + represents centers of batteries and XX the individual pits. Flash Ranging locations are shown as △ (triangles) and Sound Ranging locations as O (circles). No difference between P. Q. and R. locations is noted, as there seemed to be no systematic order of estimated accuracy. The

zone numbers, when such exist, are shown near the battery positions. The individual locations are plotted on the 1:20000 plan directeur maps of the region. Errors in the survey of the battery positions and in the plotting do not exceed 30 meters in most cases.

The following is a description of the battery positions visited by the survey parties:

C 4057. 3 batteries of 77's; easternmost position not located by either sound or flash; group of S. R. S. locations centered around one of the positions; group of S. R. S. and 2 F. R. S. not centered on any position found by survey party; strong probability of transient position because both Sound and Flash locations exist.

C 3159. Battery of 77's; 2 pits; 14 S. R. S. locations; mean position 100 meters in error.

C 1863. Two 10 cm. positions; recently active; huts and shelters; battery 77's, 4 pits; 4 S. R. S. and 1 F. R. S. location; error about 50 meters.

C 1465. 13 S. R. S. locations in general area of 2 batteries of 77's on edge of woods; most probable greatest error about 100 meters.

C 1363. Probably a mobile battery on, or near, railroad track; 7 S. R. S. locations; that furthest from R. R. track about 120 meters away.

C 1061 and 0960. Situation too confused to permit conclusions to be drawn. Area known to have been one of great activity. Possibly a number of mobile batteries in the area.

C 0460. Two separate single gun positions; that to the north, large caliber; 2 S. R. S. locations 50 meters in error. That to the south was a 77; 1 F. R. S. location 50 meters in error; 9 S. R. S. locations with maximum error of 100 meters and average error of about 40 meters.

B 9358. Active 105; 1 F. R. S. location 50 meters from nearest pit; 9 S. R. S. locations well grouped parallel to battery position; isolated S. R. S. location probably refers to single pit found on edge of road.

B 8753. Three positions; for the most southern; 4 F. R. S. locations maximum error, 150 meters; minimum, 70 meters. 16 S. R. S. locations; maximum error, 150 meters; minimum, about 10 meters. For the northernmost; 1 F. R. S. location; error 110 meters; 6 S. R. S. locations; maximum

error, 110 meters; minimum, about 10 meters. This battery was ranged on by means of S. R. S. Some of the positions were destroyed.

B 7466. Well marked 77 position on edge of woods. Two very accurate S. R. S.; one at either end of the four-gun battery; 2 poor locations; one 150 meters in error; no F. R. S. location.

B 8370. 105 Howitzer behind railroad embankment; 1 S. R. S. location within 50 meters; 3 other poor locations; poorest 300 meters in error.

B 7472. 3 batteries; that to east very active 15 cm.; 2 S. R. S. locations within 50 meters; the other two batteries were 77's; 3 S. R. S. locations; poorest 70 meters in error; no F. R. S. location.

B 6973. Single pit; no signs of activity; S. R. S. locations in this neighborhood may refer to roving piece.

B 6575. Single 105; 2 good F. R. S. locations within 40 meters; 1 S. R. S. location within 70 meters.

B 7479. Two or more batteries; one a 10 cm.; one very accurate S. R. S. location; 3 others within 150 meters; 1 very poor F. R. S. location.

B 6983. Two separate batteries; the more westerly six well marked pits 10 cm.; one good F. R. S. and one good S. R. S. location; the more easterly two 105 pits; 3 F. R. S. and 7 S. R. S. locations; in either case, poorest location 150 meters in error.

B 7485 and 7788. Situation too confused to permit drawing of conclusions. The two F. R. S. locations are evidently accurate locations of two pits on the side of the road.

B 8582. 77; 4 pits; three active and well marked; one good and three poor F. R. S. locations; 40 meters minimum and 200 meters maximum error; 3 S. R. S. locations each about 100 meters in error.

B 6994. Three S. R. S. and one F. R. S. locations in open field; very scattering; easternmost probably refer to positions on edge of woods.

B 7845. The 5 F. R. S. locations grouped about this point and the 2 S. R. S. locations near 7390 were not visited.

B 9680. 15 cm.; one very good S. R. S. location; two others within 70 meters, and two within 150 meters. No F. R. S. location.

B 0082. One F. R. S. and three S. R. S. locations within 100 meters of a location shown on airplane photograph as a battery position; positions not surveyed as coordinates given by air photo were assumed to be correct; dug-outs; ammunition, 10 cm.; 4 pits.

The group of locations about the more northerly position was visited and no signs of occupation found; all are apparently systematically in error.

C 1484. Battery of six 150's; active; 1 F. R. S. location 100 meters in error; 3 S. R. S. locations; maximum error, 100 meters; minimum, 40 meters.

North of this position was a single 150, about which are grouped 10 S. R. S. locations, with errors from 250 meters to about 10 meters.

B 8879. Single 15 cm.; three very widely scattered F. R. S. locations and nine widely scattered S. R. S. locations; all very poor if they refer to this position and not to a roving piece.

W 9205. 10 S. R. S. and 2 F. R. S. locations badly scattered.

B 8996. One good and three poor F. R. S. locations.

B 9680. 15 cm.; 5 S. R. S. locations; maximum errors, 130 meters.

B 9775. 77; one extremely good F. R. S. and two S. R. S. locations in error about 100 meters.

B 9979. 77; five S. R. S. locations; average, good.

B 9469. 105; 3 pits; well marked; a group of eight very accurate and two very poor S. R. S. locations; one very poor F. R. S. location, which may not refer to this position.

C 0780. Five pits destroyed by shell-fire; two good S. R. S. locations; error, 20 meters; one poor location 150 meters; one F. R. S. location 50 meters; one very poor, 250 meters.

C 0872. Very active battery; direct hit on one gun; 7 S. R. S. locations varying in accuracy from 150 meters to perfect location.

C 7527. 210; concrete; one F. R. S. location exact.

C 7529. Single 77; one F. R. S. location 100 meters in error.

C 7532. 105's; 4 pits under camouflage; in hollow, in thick woods; not located by F. R. S.

C 7027. Transient 77 position in open field; located without error by F. R. S.

C 7130. Transient 77 position in open field; located to within 20 meters by F. R. S.

C 7737. Very active battery of 100 longs; F. R. S. location 100 meters in error.

C 7834. Well-organized position; probably occupied at first by 150's, later by anti-aircraft; F. R. S. location exact.

The data given above and shown on the map represent fairly the work of a Sound Ranging Section about average as regards equipment and ability of personnel, and that of two Flash Ranging Sections, both of them rather handicapped by unsatisfactory equipment and both of them well-trained and capable in personnel. In neither case do the data here presented represent the total work performed in the period covered by the report. Besides the location of enemy batteries, both sections participated in ranging shoots, and the Flash Ranging Sections collected a considerable quantity of general intelligence information. A judgment of the accuracy attainable in *ranging shoots* should not be based on the data here presented, as the problem is quite a different one and susceptible of far greater accuracy in the case of Sound Ranging, and also to a lesser extent in the case of Flash Ranging.

It should be remembered in reading the report that even inaccurate observations of batteries previously located with a fair degree of accuracy are often of considerable value in reporting activity, *provided the order of accuracy of the observation is known.* The recognition by the Section Commander of the importance of systematically listing the order of accuracy of the individual locations is absolutely necessary if the section is to perform work of the highest character. Sections should report from time to time new average locations of active batteries—these averages to be estimated from weighted mean values of the locations—a proper weighing of the locations can only be made if a systematic record is kept of the degree of accuracy to be assigned to each location as judged by the character of the intersections on the plotting board.

CHA

EXTRACT FROM CHAMBLEY 5-6 & BOIS LE PRETRE

Engineer Reproduction Plant, U. S. Army, Washington Barracks, D.C. 1919 1345-AA

NOTE ON THE ACCURACY OF SOUND RANGING LOCATIONS.

The Artillery Information Service has available for the location of new enemy batteries and for the identification of old ones (a) aerial observation by airplane, (b) aerial observation by captive balloons, (c) terrestrial observation by (1) the artillery forward observation posts, (2) by other terrestrial observers in isolated posts, (3) by the groups of Flash Rangers, (d) locations by the groups of Sound Rangers. It will be observed that all these sources of observation are dependent on conditions of visibility excepting the sound ranging. In a climate where any considerable proportion of the days are foggy it is evident that sound ranging becomes on many occasions of primary importance.

Locations by sound involve, however, procedures of such a technical and complicated character that the layman is likely to look on the results obtained by it with a certain suspicion. It is consequently of high importance to investigate at every opportunity the actual degree of accuracy obtained under service conditions. This report herewith presented is concerned with a survey of captured German battery positions along the southern front of the St. Mihiel salient in an area covered by two American sound ranging sections for six months preceding the advance of September 12, 1918. The facts here presented give a definite and reliable basis for the formation of conclusions on the general value of sound ranging and on the accuracy of location obtainable with it in field operations.

Sound Ranging in the United States Army is carried on by battalions of the 29th Engineers. The detachments are in all technical matters under the direct control of G-2-C G.H.Q.—in tactical matters they are under the command of the Commanding General of the Army Artillery. Sound ranging section No. 1 was installed under the direction of G-2-C G.H.Q. about March 11 in such a way as to cover the enemy territory between grids 350 and 360 (east of Apremont to west of Mort Mare). Section No. 3 was installed about April 10 to cover from 358 to 366 (east of Maizerais to west of Reg-

nieville). The map (No. 1[a]) attached hereto shows the area covered by the sections.

The batteries dealt with by these sections may be divided according to location into the following groups from west to east—Mont Sec, Gargantua and Mort Mare-Euvezin. The approximate limits of these groupings are shown on the map (No. 1[a]). The numbers in black indicate the known batteries in each group and serve as an index of the relative importance of the groups. In this report the groups will be treated separately.

GROUP 1—MONT SEC.

This group included a number of important and continuously active batteries. The area density was, however, small so that there was a clear definition of individual batteries and no difficulty arises in allocating any particular location to its proper battery. This group, therefore, affords a particularly good opportunity for the study of accuracy of location. The batteries given in this group on the A.I.S. list issued September 8, 1918, are classified as follows:

LIST 1—A.I.S. LOCATIONS.

Active Within 30 Days	Active Within 60 Days	Active Previous to 60 Days	Suspected Locations	Total
F0538	1446	0338	0952	
0541	1861	0846	0142	
0935		0940	0837	
2648			0552	
2853			1737	
2955			1232	
3050			1440	
			1252	
			1656	
			1336	
			2773	
			2146	
			2263	
			2957	

In addition to these listed there were certain positions temporarily occupied, as for example 1450, and several of the batteries reduced in the final analysis to suspected locations have been given in the S.R.A. summaries of March and subsequent months as active.

The 1-20,000 map attached (No. 2[a]) shows on it the locations of the various batteries in the list given above. Only a few of the sus-

[a]Not printed.

pected locations are shown since they do not for the most part correspond to true battery positions.

In this same group the total different locations made by S.R. No. 1 between March and September was 20, of which 8 were on railways and roads, and one was found on examination to be a center of harassing fire of our own pieces picked up on several successive days by careless computers. Of permanent emplacements we have therefore given by S.R. a total of 11. These comprise: 0836, 0638, 0947, 1446, 1861, 2955, 3050, 2853, 2648, 2262, 2356 and 1450 (temporary).

LIST 2—S.R.S. LOCATIONS.

A barrage list prepared from the S. R. data would read as follows:

Active Within 30 days	Active Within 60 Days	Active Previous to 60 Days
0836	1446	0947
0638	1861	2262
2955		2356
3050		1450
2853		
2648		

LIST 3—BATTERIES REALLY ACTIVE.

An examination of the area immediately subsequent to the attack showed that the following batteries only were probably active up to the night of attack: 0836, 0947, 3050 (sprengminen—most recent occupation); 2855, 2853 (Sept. 5).

In addition, during the period March to September, 0638, 1861, 1446, 1450, 1336, 2648, 2362 and an unknown number of single gun transient positions were certainly active at some time. No other batteries were found that showed any evidence of activity this year.

A critical comparison of these lists leads one to the conclusion that had the artillery barrage sheets been built up on the sound ranging reports alone the results would have been more satisfactory than was actually the case when information from all sources was included. One of the most active batteries in the area, 0947, although repeatedly reported by S. R., was not listed by the Artillery at all; the S. R. locations being assigned to 0846 because that was visible on the photographs. Similarly, Battery 0836, which was given by S. R. as active within 30 days and which was as a matter of fact very active up to and possibly including the night of our

attack, is not listed at all unless it is covered by 0935 or 0837; co-ordinates on which no batteries existed. Further, amongst the emplacements listed by the Artillery, 0940 and 0338 had clearly not been active in years. Battery 0940 was, in particular, plainly marked ''Schienstellung No. 45'' and was probably maintained to cover the firing of batteries from the adjacent railway as located by S.R. No. 1 at 0739 and nearby. Still further the majority of the ''supected locations'' do not correspond to battery positions. They are mostly dug-outs, strong points, machine-gun posts, watering places for horses, etc. On examination the suspected locations in this group were found to be as below:

0952 Watering place for horses.
0142 Large camouflage—probably a transient position in 1915 or 1916.
0837 Nothing—probably meant for 0936.
0552 Nothing—open field—transient recent positions at 0453.
1737 Peculiar deep dug-out in process of construction.
1232 Nothing.
1440 Probably a misprint—top of Mont Sec.
1252 Open field—nothing.
1656 Nothing.
1336 Battery position, recent—77's. Large strong point being built close by.
2773 Not examined.
2146 Nothing—very old battery at 2246.
2263 Transient emplacement occupied this year (part of old permanent battery).
2957 Not examined.

We will now consider the accuracy of location of the individual batteries by S. R. and also the accuracy of the individual locations of the particular batteries. Such general information as was collected during the examination of the positions will be included here with the other data.

BATTERY 0538 OR 0638.

Calibre. 77 and 10.5—determined from numerous wads in front of position and also from shells and casings.

Protection. Emplacements, concrete floors and walls—overhead wire and brush—heavily concreted deep dug-outs adjacent to emplacements—well constructed deep trench connections—tar-paper houses in the woods for quiet times. All walks and approaches fully camouflaged by drawing bushes together overhead.

Direction of Fire. Mid-direction 200 mils east of south.

Communications. Narrow gauge approach from rear—recently torn up. Guns were pulled out at front by horses.

Counter-battery. Heavy counter-battery by 240's and 150's. Emplacements 2 and 3 entirely destroyed. Entire position untenable. A great proportion of the shots long and to the left (west). Recent.

	x	y
A.I.S. Coördinates (Sept. 8)	350 520	233 850
Mean S.R. Coördinates	350 612	233 885
Surveyed Coördinates (G-2-C, 2nd Army)		
Center of front	350 585	233 870

This battery was reported 13 times by S. R. No. 1 with these accuracies 1Q, 10R's, 2RR's. It was given as a 10.5 firing on Bouconville, Rambucourt and Xivray. Last reported 8-4. Judging from the wads the two emplacements farthest to the east were most used. The surveyed co-ordinates for the center of the front of these two emplacements are: x equals 350 625, y equals 233 882.

The co-ordinates above given are shown on the appended 1-10,000 map square (No. 1). The front edge of the woods in which this battery is located contains a continuous line of emplacements of varying ages but only the four most easterly ones have been in use this year. The camouflage on the westerly emplacements had decayed so that those emplacements were the more visible. This battery, 0538, was reported active by S. R. O. T. 88 three times during the period here considered but the emplacement was not visible from any of 88's posts and the flare could be seen only from one post—that at Xivray. The individual locations are shown on map square (No. 2).

It will be noted from the facts stated above that the accuracy of the location obtained by S. R. is sufficiently good, being in fact better than the location accepted by the A. I. S. as resulting from photographic restitution or from other information. We will now consider the accuracy of the individual determinations made by the S. R. group. The accuracy rating used by the American sections is as follows:

P judged to be correct within 50 meters
Q judged to be correct within 100 meters
R judged to be correct within 150 meters

RR—A location with a larger possible error than 150 meters. An RR may be as good as a P or a Q but instrumental or weather

conditions or the location of the gun with reference to the area covered by the section are such that a useful estimate of the possible error cannot be given.

The 13 locations made of 0538 are plotted on the appended map-square (No. 2). The elliptical areas marked P. Q. R. are the areas within which the P. Q. R. locations ought respectively to fall. It will be observed that all of the locations are better in accuracy than claimed. The line drawn across the figure is the target to center of base chord line, along which the major axis of the ellipse of S. R. dispersion ought to lie. The major axis does, as a matter of fact, lie roughly along this line.

BATTERY 2855 OR 2955.

Calibre. 77's and 10.5's. Last occupied by 77's. Determined from wads and from shells and casings.

Protection. Emplacements, concrete walls and floors—large enough for 150's. Overhead cover—camouflage only. Excellent, extensive and well finished dug-outs in reinforced concrete—very strong—connected throughout by concrete tunnels.

Direction of Fire. Mid-direction 200 mils west of south.

Communications. Narrow gauge railway exclusively.

Counter-battery. Slight—two or three bursts only.

	x	y
A.I.S. Coördinates (Sept. 8)	352 890	235 520
Surveyed Coördinates (G-2-C)	352 892	235 505
Mean S.R. Coördinates	352 895	235 525

Remarks. This battery was reported by S. R. 1 a total of 47 times with accuracies as follows—9Q's, 18R's, 20RR's. It was given as a 77 firing on Rambucourt, Xivray, Bouconville.

The locations given above are plotted on map square No. 3 attached hereto.

Accuracy of the Individual Locations. The figure on map square No. 4 shows the individual locations on a 1-10,000 scale. It is again to be noted that the accuracy claimed for each particular location is justified.

BATTERY 0836.

Calibre. 77 and 10.5. Identified from wads. 10.5 wads found in front of emplacements 1 and 2 only.

Protection. An extensive, well organized battery position apparently in use up to the time of our attack. Six emplacements;

but probably only two in recent use and not more than four at any one time. Emplacements with cement floors and sides to south and east, but without overhead protection excepting for corrugated iron on light timber and camouflage on wire. Excellent, deep concreted dug-outs for men in rear of position, one in stage of partial construction. Other heavy log dug-outs and special shelters for ammunition.

Direction of Fire. Direction 450 mils west of south—extreme line of fire to left.

Communications. Narrow gauge railway to center of position but guns were taken by horse through front of emplacements.

Counter-battery. None.

A. I. S. Coördinates. None unless 0935 is meant for this battery.

	x	y
Surveyed Coördinates (G-2-C) Emp. 1......	350 819	233 624
Center Front	350 835	233 585
Mean S.R. Coördinates	350 835	233 633

Remarks. This battery was reported by S. R. 12 times with accuracies of 2Q's, 5R's, 5RR's. It was given as a 105 firing on Bouconville and Xivray. The position contained a large amount of freshly fuzed 77 ammunition. Emplacements 2 and 4, counting from the north, were almost certainly in use up to the night of our advance. Last reported by S. R. 8-21. All 10.5 wads found in front of emplacements Nos. 1 and 2.

Diagrams. The coördinates given are shown on map square No. 9. The individual locations are shown on map square No. 10.

BATTERY 0947.

Calibre. 10.5 How., identified from wads and ammunition.

Protection. Installation very similar to 0836. Eight emplacements, of which two had concrete walls and floors. The others were of wooden construction. Overhead cover in all cases, either camouflage or light splinter-proofs. The concrete emplacements had both been abandoned and other emplacements made close by, which were easier of access. The position is on the forward lip of a steep ravine. Deep, safe dug-outs were provided, opening on this ravine. In addition, there were tar-paper barracks for general use. Special shelters for ammunition—position well designed and executed.

Direction of Fire. Mid-direction 400 mils east of south.

Communications. Apparently supplied from first-class road in front of position. Pieces taken out by horses from the front of the positions.

Counter-battery. None.

A. I. S. Coördinates. None.

	x	y
Surveyed Coördinates (S.R.Hdq.)........	350 920	234 710
Mean S.R. Coördinates	250 936	234 700

Remarks. In this battery emplacements 2, 4, 7 and 8, counting from the western end, were occupied up to the night of our attack. Large quantities of fuzed ammunition were found in the position. Pits 1 and 5 had been abandoned for some time past. The concreted pits were used as sentry posts or look-outs. S. R. 1 reported this battery active eight times with accuracies of 3 Q's, 4 R's and 1RR. Last reported by S. R. on 6-28.

Diagrams. The coördinates of this battery are shown on map square No. 11, the individual locations on map square No. 12.

BATTERY 1446 OR 1546.

Calibre. 203 Russian howitzer. Identified from wads.

Protection. Emplacements open—rough camouflage overhead. Pieces sunk about five feet. Very deep dug-outs for men lying between the emplacements. Excepting for low ammunition shelters no concrete work. Four emplacements—the three easterly ones the most used. A low, unimportant looking work.

Direction of Fire. 1,600 mils east of south.

Communications. Narrow gauge railway approach from rear—recently torn up subsequent to counter-battery. Guns pulled out at rear by horses.

Counter-balance. Heavy destructive counter-battery, apparently by 240's.

Three emplacements put out of action. Recent.

	x	y
A.I.S. Coördinates (May 1).............	351 500	234 600
(Sept. 8)	351 430	234 560
Surveyed Coördinates (G-2-C)............	351 450	234 560
Mean S.R. Coördinates..................	351 444	234 580

Remarks. This battery was reported by S.R. 1 a total of 16 times, including 3P's, 5Q's and 7R's. The coördinates above given are shown on map square No. 5. The mean S.R. location will be

seen to fall on the end of the battery where the more active pieces were. The battery lies on the reverse slope of Mont Sec and could not be located by any other agency than S.R., or else photographs. Particular interest attaches to it because it was the only large calibre battery in this area. The S.R. reports gave it as a 203 firing on Rambucourt, Xivray, Bouconville and Hamonville. It was last reported July 6.

Accuracy of the Individual Locations. The individual locations are plotted on map square No. 6 attached hereto.

BATTERY 2853.

Calibre. 77's—from wads.

Protection. An old emplacement, perhaps 1915 or 1916, heavily constructed of logs with deep, wet, dug-outs also constructed of logs. Five emplacements. The living quarters not used in years. The two most easterly positions, the ones nearest the road, fixed up for transient usage and recently used. Overhead camouflage of branches on wire.

Direction of Fire. Nearly due south.

Communications. A narrow-gauge railway running down through position 2855. This track was pulled up apparently before 2855 was built, that is to say, many months ago. Transient pieces brought in along the road to the east.

Counter-battery. Fairly heavy general counter-battery in neighborhood, but mostly to the east and in front. It cannot be said that the position itself was counter-batteried at all.

	x	y
A.I.S. Coördinates	352 790	235 290
Surveyed Coördinates (G-2-C)	352 820	235 280
Mean S.R. Coördinates	352 830	235 290

Accuracy of the Individual Locations. The individual locations are plotted on map square No. 8, attached hereto.

Remarks. S.R. 1 reported this battery 14 times, giving 2 Q's, 5 R's and 7 RR's. It was reported as a 10.5 firing on Rambucourt, Beaumont and Seicheprey and also as a 77 on the same targets. The 10.5 is reported in May and June, the 77 in August. It is probable that the position was occupied twice, as is here indicated. Last reported August 15, 1918. Papers found in emp. show occupation on September 5 by 77. The coördinates given above are

shown on map square No. 8. The individual locations are shown on map square No. 7.

EMPLACEMENTS NOT PERMANENTLY OCCUPIED.

In this area, as elsewhere, the enemy had numerous established, surveyed positions which he occupied only occasionally for special purposes of harassment or for the support of raids.

BATTERY 2648.

Calibre. Last used for 77's. Determined from wads.

Protection. Open emplacements with semi-circular breastworks. No shelter for men. Guns when in place were camouflaged with loose branches. Six positions. Numbers 4 and 6 counting from the west end were certainly in recent use. Number 3 may have been used this year. The others had not been used in years.

Direction of Fire. About 250 mils east of south.

Communications. Guns brought in along a dirt road from edge Bois Nouveau.

Counter-battery. Distributed shelling nearby—probably not directed at this battery.

			Center of 6 Center of active emplacements	
	x	y	x	y
A.I.S. Coördinates	352 580	234 770		
Surveyed Coördinates	352 580	234 765	352 620	234 775
Mean S.R. Coördinates...........	352 600	234 788		

Remarks. S.R. 1 detected this battery in action August 2, August 3, August 4, August 5, August 6 and August 7. It was reported as a 77 firing on Rambucourt, Beaumont and Bois du Jury. 11 locations were made, including 5 R's and 6 RR's.

Diagrams. Map squares Nos. 14 and 15 show the data obtained on this battery.

BATTERY 1861.

Calibre. Transient positions for both 77 and 10.5. Evidence—wads.

Protection. Open positions—wire and camouflage of branches overhead. Shallow trenches around gun positions and trench shelter for men. A single poor log shelter in the rear of the position. Four positions—Nos. 2 and 3 recently used by 77's; No. 4 last used by a 10.5.

Direction of Fire. About 500 mils east of south.

Communications. First-class road immediately at the rear of the position.

Counter-battery. Marks of recent counter-battery—probably during the push. One heavy burst near No. 2 position. A number of recent heavy bursts about 100 to 150 meters short of battery.

	x	y
A.I.S. Coördinates	351 830	236 080
Surveyed Coördinates	351 930	236 070
Mean S.R. Coördinates	351 888	236 130

Remarks. S.R. 1 located this battery 5 times, 2 Q's, 2 R's and 1RR. This is not a sufficiently large number of independent locations to give a first-class mean location. The surveyed location does not check with the map detail. From the map detail the y is 236 100. The coördinates of the locations above shown are shown on map square No. 16. The individual locations are shown on map square No. 17.

POSITIONS ON RAILWAYS.

The enemy made extensive use of guns mounted on light railway cars. The degree of success with which S.R. met in dealing with these guns can be judged from map square No. 20. The figure shows individual locations, which belong in all probability to three firing positions at A, B and C. At A and B definite evidence was secured in the form of gun wads and shell cases of the firing of pieces in these vicinities. The figure shows all of the scattered locations obtained by S.R. 1 in this particular area. The dates of location show that the guns remained active for three or four days in one position. On this part of the front the enemy had three centers of transient fire, of which this is one. The others were the gap to the east of Mont Sec and the region of the Etang de Bailly.

EXTREME FLANK LOCATIONS.

The area which a Sound Ranging Section is supposed to cover well is that lying between the perpendiculars erected at the ends of the base chord. These limits are set by mathematical and physical considerations. In our service this area is extended to cover to a line one kilometer outside these perpendiculars, but beyond these lines no locations are reported as better than RR accuracy. That the extension to 1 km. outside the perpendiculars is justified is proven by the excellent location of batteries 0836, 0638 and 0947, all of which lie in the extra kilometer. The locations made by S.R.

of battery 8929, which lies 3300 meters outside the perpendiculars, serve to show the errors which may be expected in extreme flank locations. "8929" was reported 5 times; three locations being rated R's, although all should have been reported RR's to the artillery. The results follow:

	x	y
A.I.S. location—Not recorded by 4th Corps		
Surveyed location (center front) G-2-C....	348 930	232 960
Mean S.R. location	349 020	233 060

In examining the individual locations as shown on map square No. 18, extreme errors in range are to be noted, as would be expected, but the line is consistent so that in sparsely occupied areas a battery might thus be identified with a degree of precision similar to that which Flash Ranging and other observers get from single ray observations. The more, however, that one notes the extensive use by the enemy of transient positions, the more it becomes apparent that single ray observations of any kind not checked by other evidence are valueless. In S. R. work it is therefore best to give no results at all, even of RR rating, outside 1500 meters from the perpendiculars to the base chord.

Calibre. 150 howitzer.

Protection. Emplacements open overhead, excepting for camouflage. Breast-works, logs and dirt—recent. Excellent living quarters for men—small shacks with dugouts behind. Deep tunnel shelters for ammunition. Large quantites of ammunition on hand.

Direction of Fire. Mid-direction about 650 mils south of west.

Communications. By road along the bed of an abandoned narrow-gauge railway.

Counter-battery. None.

Coördinates. See above.

Remarks. Installation remarkable in that the line of fire is only about 10 degrees away from the line of emplacements. The pieces fired very nearly over one another and over the shacks in which the men lived at the distance of a few feet.

In this report all the locations made in the areas considered are given. There are no selections and no omissions. The data therefore represents the actual facts and do not reflect the beliefs or opinions of the compiler.

The mean S.R. locations referred to in this report are weighed means, in which the weights are assigned on the basis of the rated

P, Q, R and RR accuracies. P locations are arbitrarily rated 4; Q, 3; R, 2; RR, 1.

The P, Q and R ratings as referring to any one location give the computing officer's critical estimate of the technical excellence of the determination. These locations result from a mathematical-physical procedure of such a nature that, if the wind and other corrections are properly applied and the atmospheric conditions are properly evaluated, the final result must positively indicate the exact source of the sound. There are in practice always certain possible errors, the limits of which must in each case be estimated by the computing officer. Although the computing officer's estimate will be more or less valuable, depending on his general grasp of the physical problem and on his knowledge of the determining factors and of their mode of variation, the data here submitted show that in our service these estimates were generally fairly true. It is evident that P locations average better than Q, Q's better than R, and R's better than RR's, and that a location, judged by a competent computing officer in the light of known weather, instrument and line conditions to be within the limits of error of one of these categories, is to a high probability actually within these limits. There are, nevertheless, possibilities for a considerably greater variation in any one individual location than might be expected. These variations are due largely to an insufficiently accurate knowledge of the weather conditions.

It is clear that since the nature of the errors involved is accidental, the average of any considerable number of locations, in themselves inaccurate, is certain to be of a much higher degree of dependability. Four or five locations made under different weather conditions constitute a considerable number in the sense here used, and the mean of these four or five can be depended upon to be close to the true battery location, even though the constituent data are all of "R" accuracy. These facts are fairly well demonstrated by the evidence examined. This statement can be otherwise expressed by saying that five or more independent "R" locations enable us to place a battery with "P" accuracy or better. It is because of these facts that Section Commanders in our service have been directed to distinguish in orders of accuracy the accuracy to be ascribed, in the judgment of the computing officer, to any one location and the accuracy of determination of a battery position from a series of observations. The order of accuracy of the mean position will, as above pointed out, be always higher than that of

the constituent data and can only properly be determined through a consideration of the number of independent values involved in the mean. A battery location should be rated R on a single determination because of our necessarily uncertain knowledge of the weather conditions, although the film itself may be judged P or Q. A ''Q'' can, however, safely be given to the weighted mean of four or five locations irrespective of the ratings of the individual determinations and a P can similarly be assigned to the weighted mean of eight or ten locations. The attached data show that a P battery location is safe to 25 meters. The principal factor entering into the accuracy rating of a battery position is seen to be the number of locations obtained of whatever accuracy, but it will be understood that the giving of an order of accuracy to a battery location cannot be reduced to a mere mechanical consideration of the number of independent determinations involved, even though it is mainly based on this number. The grouping of the locations should be considered and should be found normal. A normal grouping is roughly elliptical with an axial ratio of 1 to 3 or thereabouts. The major axis lies roughly on the line, battery to center of base chord.

The batteries discussed in the group covered by this paper (the Mont Sec group) are selected from this group as typical. Persons studying this report can safely accept the conclusions to which it leads without waiting for the reports on other groups. There is no essential difference in the character of the results obtained in the different groups or in the batteries of any one group.

We can sum up by saying that a single Sound Ranging location rated P, Q or R is to a high degree of probability within the limits of error stated for these ratings; that a mean Sound Ranging location comprising seven to ten or more individual determinations is to a considerable degree of certainty within 25 meters of the activity center of the battery. In consequence it is probably just to conclude that Sound Ranging is in general practice more dependable for compiling lists of active batteries and for detecting the active part of a given battery, than any other agency. It should, however, be pointed out that the highly technical procedures involved and the breadth of general scientific knowledge required to get results of this grade consistently, demand a highly qualified, highly trained and experienced personnel and a properly handled apparatus of the general character of that in use by our sections.

The attention of readers of this report is directed to the fact that the methods used for locating active batteries by S.R. are not

the ones made use of in ranging our artillery on an objective. The placing of the bursts relative to one another is accomplished by other procedures which enable us to report the relative positions to a considerably higher degree of accuracy. It will be seen that a dispersion of locations of successive bursts, such as is shown on the attached map squares, would be of no use in correcting artillery fire. This dispersion results from the dissimilarity of weather conditions on different days. The results obtained from any one battery at any one time, roughly speaking within three or four hours, invariably check very closely indeed with one another; but these successive determinations do not appear on our records, being looked upon as duplications.

GROUP 2—GARGANTUA GROUP.

The limit of the Gargantua group are shown on Map No. 1. This group lay in the center of No. 1's base and contained a number of batteries—particularly 3751, 3749, 3855 and 5660—which, during February and March, were very troublesome to the American divisions facing them. S. R. No. 1 was installed primarily to cover this group.

The A.I.S. list for September 8th, 1918, classified these batteries as follows:

LIST No. 1—A.I.S. LOCATIONS.

Active Within 30 Days.	Active Within 60 Days.	Active Previous to 60 Days.	Suspected.
3466	3751	3749	3247
3855	4758	3453	3853
4667	5058	3646	4040
4759	5061	3846	4935
4868	5456	4454	4556
5355	5463	4148	4050
5369	5763	4258	4105
5556		4547	4551
5560		5734	4262
5561		6062	5241
			5668
			5357
			5057
			5452
			5951
			5474
			5966
			6157
			6266
			6369
			6639
			6755

During the period March to September S.R. No. 1 located in this area 22 batteries. These, classified according to activity, are given below:

LIST No. 2—S. R. S. LOCATIONS.

Active Within 30 Days.	Active Within 60 Days.	Active Previous to 60 Days.
3466	3751	3453
4454	3855	3646
4868	4759	3846
5369	5357	3937
5660	5474	4258
5761	5457	5561
5763	5567	6062
		3749

Omitting any reference to the suspected locations it will be seen that we have on the A.I.S. list and not on the S.R.S. list, the following batteries:

LIST No. 3—ON A.I.S. BUT NOT ON S.R.S.

30-Day List.	Remarks (based on examination of the area subsequent to the enemy retreat).
4667	—Anti-Aircraft not examined.
5355	—no trace of emplacement here—strong point in trenches.
5556	
5560	—two old batteries—not active in several years—ruins.
4758	—no trace of battery here—perhaps meant for 4759 A. A.
5058	—not examined.
5061	—not examined
5463	—nothing here—perhaps a battery in 1915—doubtful.
Previous List.	
4148	—old battery position—probably active.
4547	—not examined.
5734	—in front trenches—unlikely unless minenwerfer.

LIST No. 4—ON S.R.S. BUT NOT ON A.I.S.

30-Day List.	Remarks.
5660	—center of ten very active emplacements—covered by 5560 on A. I. S. list.
5761	—two, certain, transient position in field—recent use—part of 5660 group.
60-Day List.	
5357	—recent transient position—ammunition—spade marks, etc.
5474	—suspected location of A. I. S.—not examined.
5567	—not examined—probably same as suspected 5668.
5457	—semi-transient position—Art. Stell. 106.
Previous List.	
3937	—old position—front trenches—2 locations only—probably minenwerfer.

It will be seen here, as in the Mont Sec group, that a barrage list made up from S.R. data alone would have been more reliable, effective and economical than the one actually used compiled from all sources. The list of "suspected locations" was not examined in full; but such information as was collected is shown below.

Suspected by A.I.S.	Remarks.
3247	
3853	—large dugout.
4040	
4935	
4556	—nothing in this vicinity.
4050	
4105	—? ?
4551	
4262	—dugouts and barracks.
5241	
5668	
5357	—transient 77 position.
5057	—no battery but probably transient pieces.
5452	
5951	—no battery—target range perhaps.
5474	—old concreted destroyed emplacements—close to transient emplacements.
5966	—a heavy battery, considerably used probably within 30 days—150 howitzers.
6157	
6266	—no battery here—recent active battery at 6366.
6369	—no battery in this vicinity.
6639	—in front lines.
6755	

We will now proceed to give the detailed data referring to the more important batteries of this group.

BATTERY 3749—BATTERY 3751.

Calibre. 77 and 10.5—From wads and old ammunition.

Protection. First-class emplacements—heavy concrete and log fronts, logs set vertically—strong concrete sides—camouflage roofs, strong concrete dugout for P.C.—tar paper barracks for men—No. 1 not so recently used, probably had 10.5 in it last—Nos. 2, 3 and 4 most recently used by 77, but 10.5 wads in front of 3. Emplacements distributed as shown on Map—Nos. 1 and 2 form battery 3749—Nos. 3 and 4 battery 3751.

Direction of Fire. All four about 30 degrees east of south.

Communications. Narrow-gauge carefully camouflaged down line of emplacements about 20 meters in the rear—stops behind No. 2.

Counter-battery. Heavy and very effective recent counter-battery by 155's—all four emplacements untenable, 1 and 2 practically destroyed. Several shoots with 155 ranged by S.R.S. No. 1 on this battery.

		x	y		x	y
A.I.S. Coördinates given as 77's—	3751	353 740	235 065	3749	353 675	234 910
Surveyed Coördinates (center) G-2-C—	3751	353 745	235 050	3749	353 700	234 955
Mean S.R. Coördinates—	3751	353 755	235 079	3749	353 720	234 940

Remarks. Map squares Nos. 23 and 24.—a very active battery in March, April and May—last reported—3749 on May 21st—3751 on July 23rd. These batteries apparently contained howitzers and guns at the same time in different emplacements.

BATTERY 3855.

Calibre. 77. From wads, baskets and ammunition.

Protection. Four recent 77 emplacements on ground—no protection—camouflage on poles, in front of four very large, almost completed emplacements with deep dugout at sides and full deep trench system connecting Nos. 1, 2 and 3. No. 4 by itself—not completed—never occupied. Nos. 1, 2 and 3 had been used recently by 77's—the new 77 emplacement. Nos. 2 and 3 were directly in the gun apertures of the big emplacements. To the right, open, camouflaged position for a 15 cm. Howitzer, used considerably—no living quarters for men, but 200 meters in front is a very deep, extraordinary large dugout system for a large number of men—a very expensive piece of work.

Direction of Fire. Five degrees east of south.

Communication. Narrow-gauge 150 meters in front. Ammunition dump there. The guns were pulled out at front by horses.

Counter-battery. Considerable counter-battery in front—no serious effects on battery.

	x	y
A.I.S. Coördinates (as a 77)	353 760	235 460
Surveyed Coördinates (center of front) G-2-C	353 755	235 458
Mean S.R. Coördinates	353 787	235 460

Remarks. Reported by S.R. 17 times—7 Q's, 6 R's and 4 RR's—last reported as a 77, and once as a 10.5 firing on Rambucourt and Beaumont—last reported August 2nd. An active battery area—difficult to be certain that the two short Q's are not from a position in front of 3855 and the two long Q's from a position behind. The position behind had two 12 cm. Belgian breech-loading rifled guns (Liege 1866) in it—a very old type of gun, almost certainly used, but probably not this year, and not merely dummies. Breech mechanism gone—still in place November 15th—old type 12 cm. shrapnel fragments (red shell, five copper bands) not unusual in fields near Xivray and Rambucourt—may have been from these guns—trees cut down in front of 3855 over a large area, say 5 acres, to give field of fire. Map squares Nos. 25 and 26.

BATTERY 3466.

Calibre. Anti-aircraft, probably 77 from shell baskets.

Protection. One weak dugout—no trace of emplacements, but sighting bars and other instruments in place—ammunition shelters of concrete slabs as in other anti-aircraft positions.

Communication. Close to narrow-gauge.

Counter-battery. Whole area torn up with 240's or 270's. This counter-battery was almost undoubtedly intended for the important dump and network of roads at Etang Champrez—short 400 to 500 meters—road crossing untouched.

	x	y
A.I.S. Coördinates	353 400	236 600
Surveyed Coördinates. From map detail (instrument stand)	353 360	236 700
Mean S.R. Coördinates	353 381	236 720

Remarks. Located by S.R. 32 times—4 Q's, 16 R's, 12 RR's—given as an anti-aircraft—last reported September 3rd—first reported July 30th—very active. Map square No. 27.

BATTERY 4258.

Calibre. 77—from wads and baskets.

Protection. Open emplacements on ground level—camouflage of branches—no construction excepting split log ammunition shelters—no living quarters—excellent, extensive, deep dugout settlement across the road, distance 50 meters (Gargantua Lager)—men doubtless lived there.

Direction of Fire. About 10 degrees east of south.

Communication. Along good road passing position—narrow-gauge on the road.

Counter-battery. Heavy, destructive counter-battery to east of position and about emplacement No. 4. Though no trace of this emplacement, it is very doubtful if there were but three to begin with.

	x	y
A.I.S. Coördinates (as a 77).	354 235	235 835
Surveyed Coördinates. From observation post (G-2-G)..	354 215	235 835
Mean S.R. Coördinates	354 190	235 849

Remarks. The three locations as shown here check well with each other, but they do not check with the map detail for the position where the battery was found by the compiler of this report, by about 100 meters—this must be further investigated. Reported by S.R. 29 times—1 P, 8 Q's, 16 R's, 4 RR's, as a 77, firing on Seicheprey, Xivray, Rambucourt and Beaumont—originally discovered by S.R. 1 March 3rd—very active April 1st to April 19th—reoccupied June 5th to June 21st—last reported active June 21st—Map square 28.

BATTERY 4759.

Calibre. Long 77—from shell cases.

Protection. Two emplacements on surface of ground—platform marks visible—guns when in position camouflaged with brush—no protection excepting concrete slabs for ammunition shelters—extensive living quarters (shacks) in woods 75 meters to west—one very deep, two entrance dugouts of recent reconstruction.

Direction of Fire. Trail marks gave mid-direction about 45 degrees east of south. Position was apparently an anti-aircraft with special gun mountings.

Communication. 30 meters to third-class road—ground marshy.

Counter-battery. None.

	x	y
A.I.S. Coördinates as an anti-aircraft	354 670	235 880
Surveyed Coördinates (center) G-2-C	354 650	235 875
Mean S.R. Coördinates	354 688	235 831

Remarks. This position could only be found by a person of experience, as the traces had disappeared in the marshy ground—it is fairly clear that the surveyors located some shelters in the rear of the position, describing them as ''piles of brush'' (see survey notes). The X coördinates of the battery are therefore probably 354 680—interesting traces of instrument and tripod stands—board to rear of position marked ''Flakstellung'' (Anti-Aircraft posi-

tion). Reported by S.R. 23 times—6 Q's, 16 R's, 1 RR, as an anti-aircraft—last reported July 15th—very active June 7th to June 15th—Map square 28.

BATTERY 4868.

Calibre. 77—from wads, cases and ammunition.

Protection. Well developed position in woods—four emplacements of logs and earth—very recent work—No. 4 not yet completed—Nos. 1 and 2 most used—living quarters in rear—shacks—no good protection.

Direction of Fire. Mid-direction of fire about 60 degrees south of east.

Communication. Curved spur of narrow-gauge well camouflaged with bushes drawn together over it, in immediate rear of emplacements—push cars used—supplied by dump on narrow-gauge on north edge of Etang de Lampinot—dump at junction—this is one reason why Nos. 1 and 2 were used the most—guns pulled out at rear by horses.

Counter-battery. No counter-battery on position itself.

	x	y	x	y
A.I.S. Coördinates as a 77..........	354 830	236 832		
Surveyed Coördinates	354 870	236 880	354 840	236 860
	(Center No. 4)		(Center Nos. 1 and 2)	
Mean S.R. Coördinates.............	354 850	236 820		

Remarks. This battery was very active up to or during the night of our advance, judging from the large amount of fused ammunition (pin type E.K.Z., etc., pin in place), piled beside the emplacement, and the recent blast marks on the bushes—large area of trees cut down to clear line of fire—originally discovered by S.R. on April 7th—located 41 times, 1 P, 7 Q's, 20 R's, 13 RR's. Given as a 77 firing on Mandres, Beaumont, Seicheprey, Bois de Jury and Bois de Hazelle—very active from April 7th to April 23rd—less active in May—very active again from June 15th to September 3rd—last reported on September 3rd. Considering the large number of locations, the final S.R. position does not check as well as might be expected, with the surveyed position—there seems to be no reason to doubt the survey—unlike most of the lakes in the area, Lambepinot contained a considerable amount of water—it is fair to assume that this body of water, about one kilometer in

length, close in front of the battery, interfered with the S.R. results in the way here seen—Map square 29.

BATTERY 5369.

Calibre. 10.5 and 15 cm. Howitzer—wads found—may be possible that 77's were also at one time in the position—a transient emplacement, considerably used.

Protection. Open wooden platforms—four positions—platforms torn up and emplacements hard to locate—no living quarters or shelters excepting trenches and ammunition shelters—very deep, and somewhat peculiar dugouts under construction about 80 meters to southeast of battery.

Direction of Fire. About 30 degrees east of south.

Communication. Narrow-gauge in front—the same one that passes 4868—road also near by—guns taken in and out by horses.

Counter-battery. None in position proper.

	x	y
A.I.S. Coördinates as a 77	355 280	236 910
Surveyed Coördinates, center of emplacements found	355 270	236 890
Mean S.R. Coördinates	355 225	236 897

Remarks. The surveyors failed to find emplacements Nos. 1 and 2, as the platforms were torn up. These are shown on Map squares Nos. 7 and 8 in proper place, as determined by subsequent checking by the compiler of this report. Located by S.R. 9 times, 5 Q's, 3 R's, 1 RR—given sometimes as 77 gun, and other times as 10.5 Howitzer, firing on Bernicourt, Seicheprey, Xivray, Beaumont and Rambucourt—active May 28th to May 30th, June 1st to June 15th, and last reported August 12th—Map square 30 and 31—the dugouts in front consisted of deep conical holes, perhaps 18 to 20 feet flat at the bottom, with the deep dugouts going off from the bottom of the hole—similar ones near battery 5655 in a minenwerfer strongpoint.

BATTERY 5660 (OR 5560).

Calibre. 77—from wads and ammunition.

Protection. Open emplacements on surface—low breastworks in front—camouflage on poles overhead—no living quarters—earth pits for ammunition—men lived in Bois L'Etang.

Direction of Fire. About 50 degrees south of east.

Communication. Field road—third class.

Counter-battery. Heavy general counter-battery in area of Etang Le Bailly—nothing on battery itself.

	x	y
A.I.S. Coördinates	355 520	236 020
Surveyed Coördinates, G-2-C (see remarks)	355 550	236 060
Mean S.R. Coördinates	355 610	236 085

Remarks. This area in and near the Etang Le Bailly had excellent defilade and easy communication to the vicinity of Nonsard—it was used very extensively for transient occupation—the S.R. forward observers invariably reported the bulk of new fire during raids to come from this area—there were ten emplacements on the peninsula by the farmhouse—No. 1 (west of house), and No. 2 (in ruin of house) had been used by 77's, but not this year—No. 3 lay against the east wall of the house, and No. 4 was about 25 paces east of it—Nos. 5 and 6 lay to either side of the line of the dam extended—No. 7 lay by itself, 100 meters farther east—Nos. 8, 9 and 10 were in a row about 70 meters still further east, out in the field—Nos. 3, 4, 5, 6 and 7 had been very active very recently, up to or inclusive of the night of the attack—they last contained 77's—these emplacements were not all considered by the surveyors, who reported only three of them, Nos. 1, 2 and 3—the coördinates range from 355 500 to 355 800
236 000 236 200 the five active positions lay between 355 540 and 355 690. The mean center of activity was 355 630—
236 040 236 135 236 080
these figures are taken from the map detail checked against the three emplacements surveyed—the S.R. position is seen to be particularly good when the complexity of the battery positions in the area is considered—located by S.R. 15 times, 2 Q's, 7 R's, 6 RR's—given as a 77 and 10.5 firing on Rambucourt, Beaumont, Mandres, etc.—last reported August 19th—Map squares 31 and 32.

BATTERY 5561.

Calibre. 77—from wads and ammunition.

Protection. Four emplacements—heavy concrete construction—evidently old and reconstructed—the type of emplacement favored about 1915 to 1916—heavy concrete structures near for men—No. 4 the most recently and extensively used, possibly the only one in recent use.

Direction of Fire. Mid-direction east of south, perhaps 30 degrees east of south.

Communication. Ordinary road—narrow-gauge northwest of pond.

Counter-battery. Very heavy emplacements practically destroyed, but in use up to very recently.

	x	y
A.I.S. Coördinates	355 500	236 140
Surveyed Coördinates, G-2-C (center of 4)	355 520	236 145
Mean S.R. Coördinates	355 520	236 170

Remarks. Located by S.R. 20 times—3 Q's, 11 R's, 6 RR's—last reported June 11th as a 77 firing on Seicheprey, Rambucourt, etc.—Map squares 31 and 32.

BATTERY 5763 (OR 5863).

Calibre. Anti-aircraft 77 combined with transient 10.5 in same edge of woods—four circular concrete piers found for anti-aircraft—numerous wads in west corner of woods evidence a 10.5 Howitzer.

Protection. The anti-aircrafts on concrete piers as above stated—Nos. 1 and 2 built into old gun positions near west corner of wood—living quarters in woods.

Counter-battery. None on position.

	x	y
A.I.S. Coördinates as a 10.5	355 660	236 260
Surveyed Coördinates, G-2-C, A.A. Position	355 725	236 280
Mean Sound R. Coördinates, for 10.5	355 696	236 296
Coördinates, from Map Detail	355 710	236 280

Remarks. S.R. made 18 locations—4 Q's, 5 R's, 9 RR's—reported as a 10.5 Howitzer or 77 with bursts on Beaumont-Bois du Jury region. The Anti-Aircraft was reported on four occasions only—the surveyors missed the second pair of anti-aircraft columns which lie at about 355 840—Map square 33.
236 280.

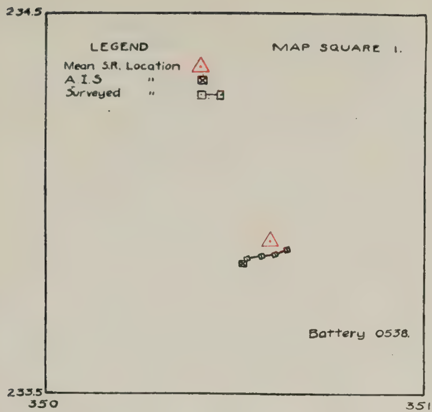
BATTERY 5457.

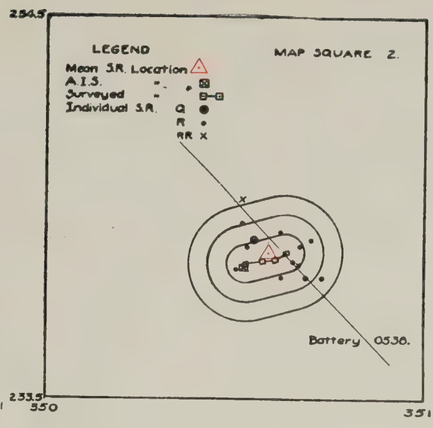
Calibre. Transient surveyed 77 position—from wads and piles of ammunition.

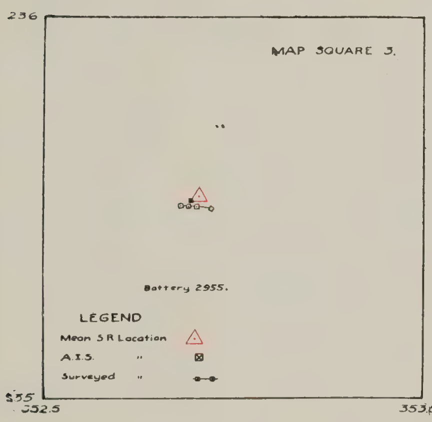
Protection. Open position—ground level—dead branch camouflage for pieces.

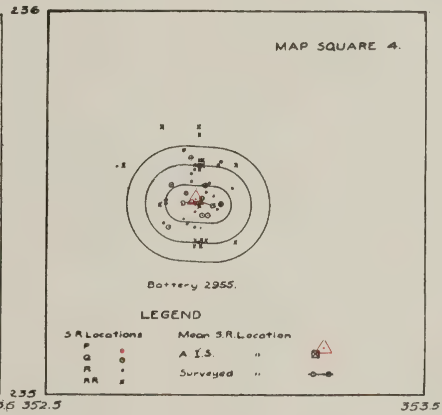
Direction of Fire. About 30 degrees east of south.

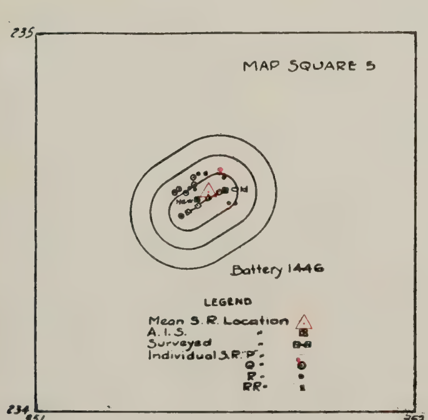
Communication. Up country road alongside of bed of Etang Le Bailly.


234.5
LEGEND
MAP SQUARE 1.
Mean S.R. Location
A.I.S. "
Surveyed "
Battery 0538.
233.5
350
351


234.5
LEGEND
MAP SQUARE 2.
Mean S.R. Location
A.I.S. "
Surveyed "
Individual S.R. Q
R
RR
Battery 0538.
233.5
350
351

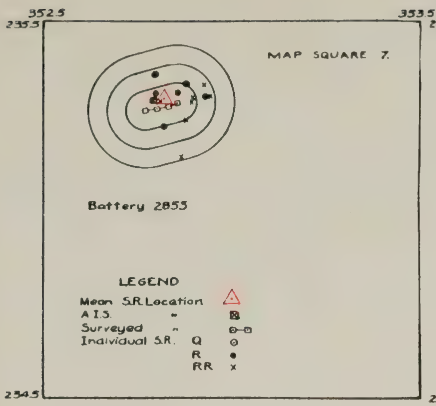

236
MAP SQUARE 3.
Battery 2955.
LEGEND
Mean S.R. Location
A.I.S. "
Surveyed "
235
352.5
353.5

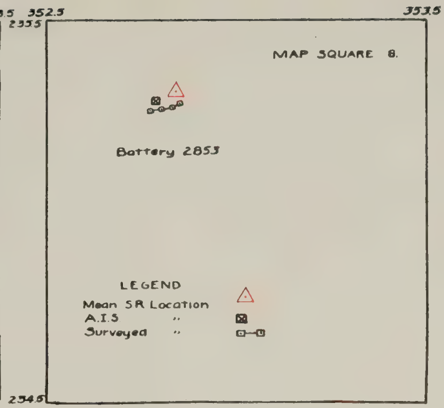

236
MAP SQUARE 4.
Battery 2955.
LEGEND
S.R. Locations
P
Q
R
RR
Mean S.R. Location
A.I.S. "
Surveyed "
235
352.5
353.5

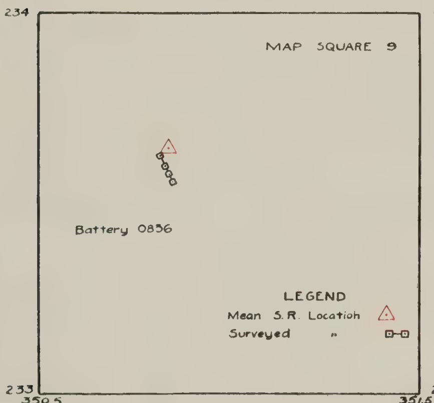

235
MAP SQUARE 5
Battery 1446
LEGEND
Mean S.R. Location
A.I.S. "
Surveyed "
Individual S.R. P
Q
R
RR
234
351
352

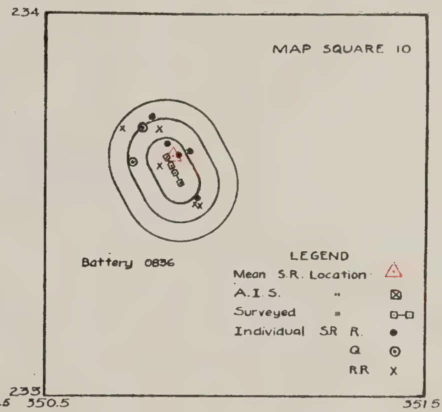

235
MAP SQUARE 6
Old
Battery 1446
LEGEND
Mean S.R. Location
A.I.S. "
Surveyed "
234
351
352

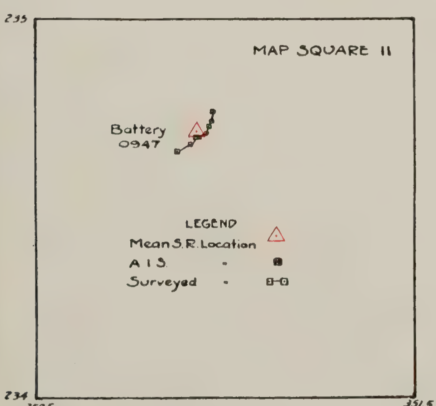
THE LIBRARY
OF THE
UNIVERSITY OF ILLINOIS

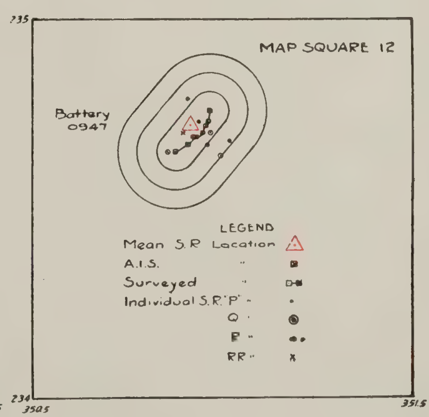

352.5
353.5
235.5
234.5
MAP SQUARE 7.
Battery 2853
LEGEND
Mean S.R. Location
A.I.S. "
Surveyed "
Individual S.R. Q
R
RR


352.5
353.5
235.5
234.5
MAP SQUARE 8.
Battery 2853
LEGEND
Mean S.R. Location
A.I.S. "
Surveyed "

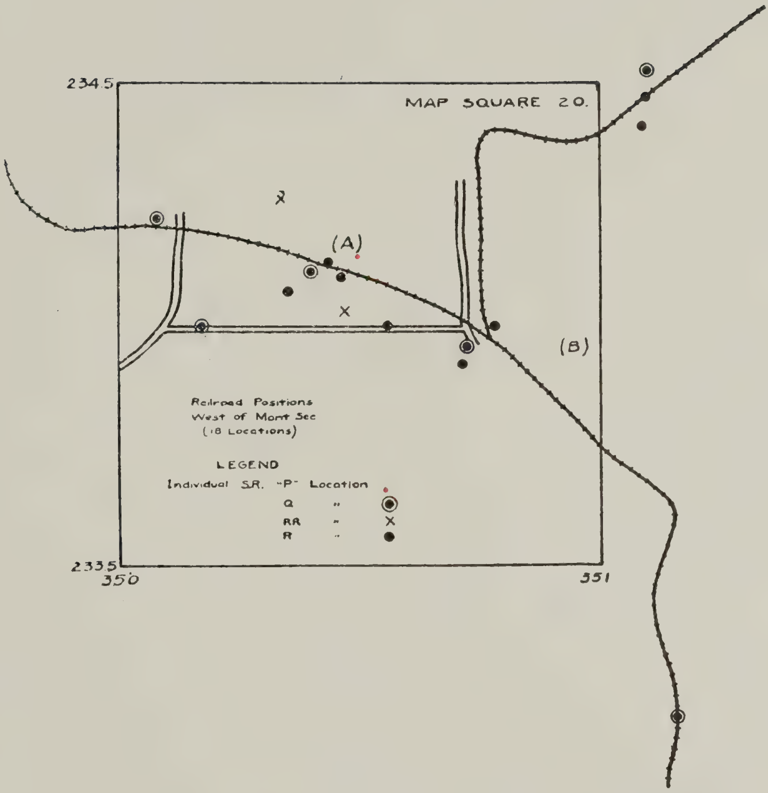

234
233
350.5
351.5
MAP SQUARE 9
Battery 0836
LEGEND
Mean S.R. Location
Surveyed "


234
233
350.5
351.5
MAP SQUARE 10
Battery 0836
LEGEND
Mean S.R. Location
A.I.S. "
Surveyed "
Individual S.R. R.
Q
RR

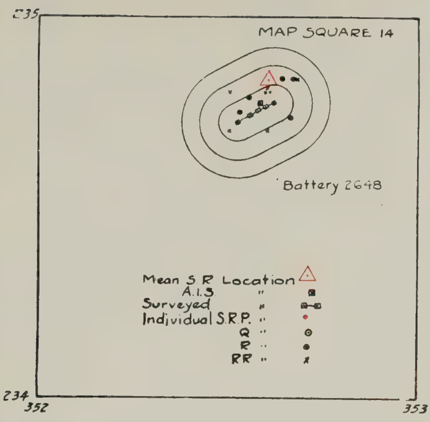

235
234
350.5
351.5
MAP SQUARE 11
Battery 0947
LEGEND
Mean S.R. Location
A.I.S. "
Surveyed "

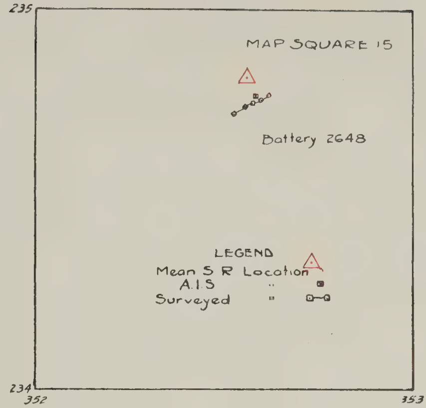

235
234
350.5
351.5
MAP SQUARE 12
Battery 0947
LEGEND
Mean S.R. Location
A.I.S. "
Surveyed "
Individual S.R. "P" "
Q "
R "
RR "

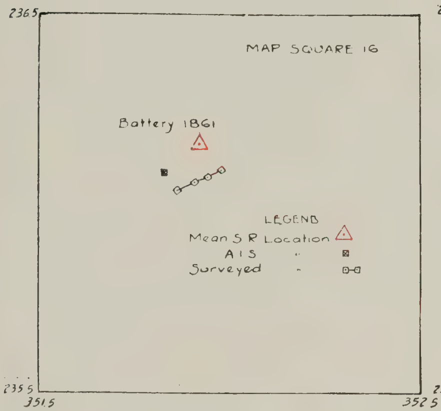
THE LIBRARY
OF THE
UNIVERSITY OF ALBERTA

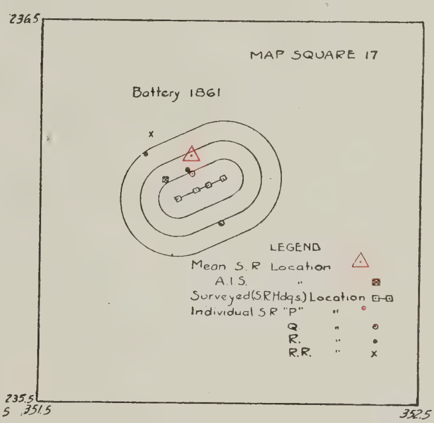

234.5
MAP SQUARE 20.
(A)
(B)
Railroad Positions
West of Mont Sec
(18 Locations)
LEGEND
Individual S.R. "P" Location
Q "
RR "
R "
233.5
350
351

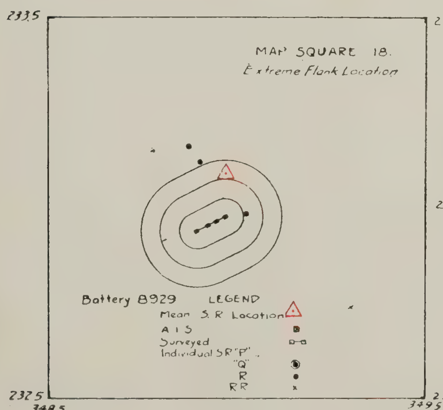
[illegible]
OF THE
[illegible]

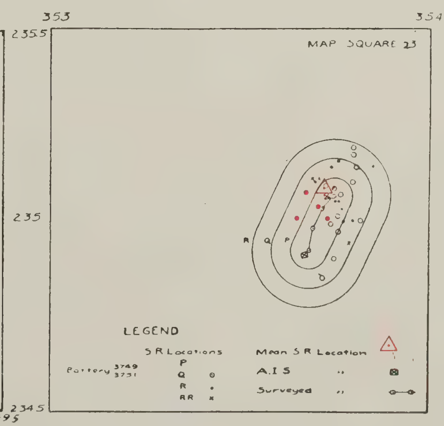

MAP SQUARE 14
Battery 2648
Mean S.R. Location
A.I.S. "
Surveyed "
Individual S.R.P. "
Q "
R "
RR "
235
234
352
353


MAP SQUARE 15
Battery 2648
LEGEND
Mean S R Location
A.I.S "
Surveyed "
235
234
352
353

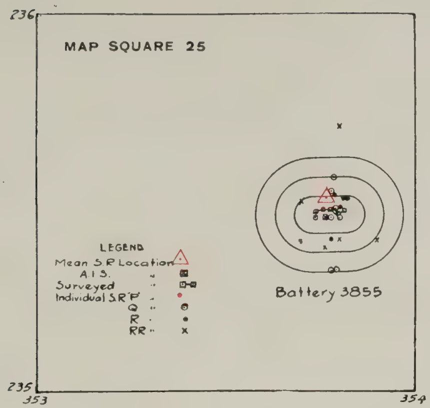

MAP SQUARE 16
Battery 1861
LEGEND
Mean S R Location
A I S "
Surveyed "
236.5
235.5
351.5
352.5

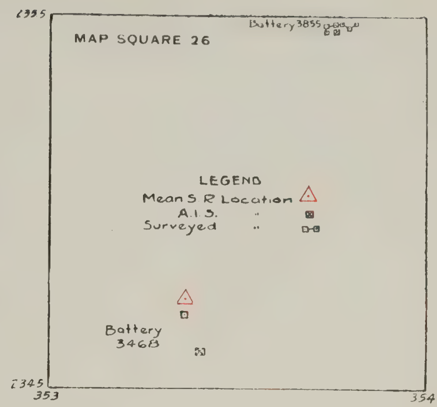

MAP SQUARE 17
Battery 1861
LEGEND
Mean S. R Location
A.I.S. "
Surveyed (S R Hdqs.) Location
Individual S R "P" "
Q "
R. "
R.R. "
236.5
235.5
351.5
352.5

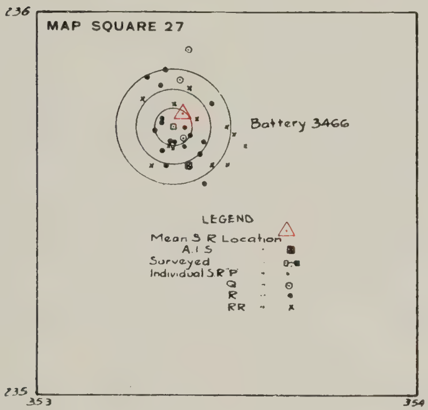

MAP SQUARE 18.
Extreme Flank Location
Battery 8929
LEGEND
Mean S. R Location
A I S
Surveyed
Individual S R "P"
"Q"
R
RR
233.5
232.5
348.5
349.5

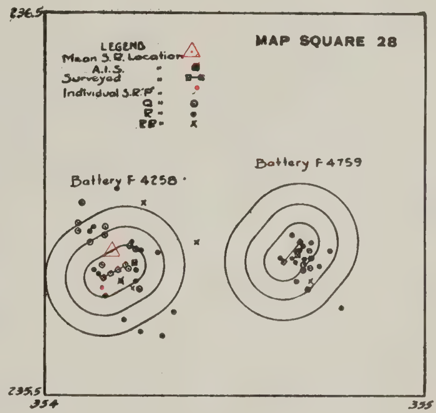

MAP SQUARE 23
LEGEND
S R Locations
P
Q
R
RR
Battery 3749 3751
Mean S R Location
A.I.S "
Surveyed "
353
354
235.5
235
234.5

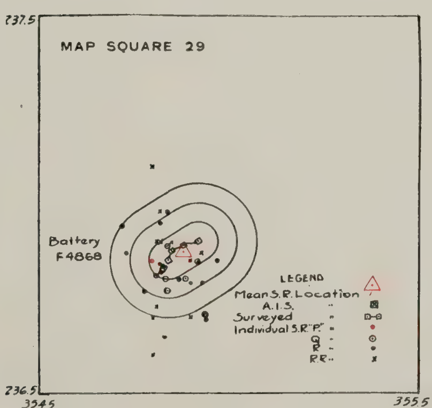
[illegible]
[illegible]
[illegible]

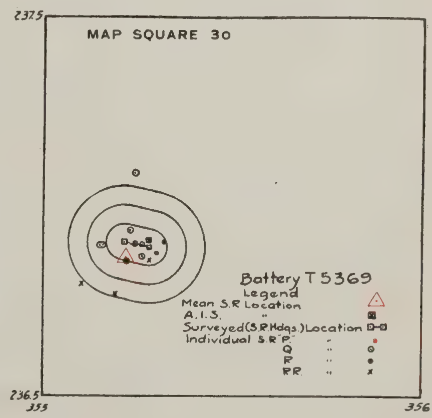

MAP SQUARE 25
236
235
353
354
Battery 3855
LEGEND
Mean S.R Location
A.I.S.
Surveyed
Individual S.R.P.
Q
R
RR

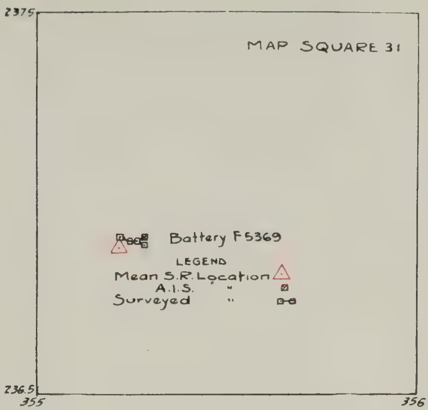

MAP SQUARE 26
235.5
234.5
353
354
Battery 3855
LEGEND
Mean S.R Location
A.I.S.
Surveyed
Battery 3468

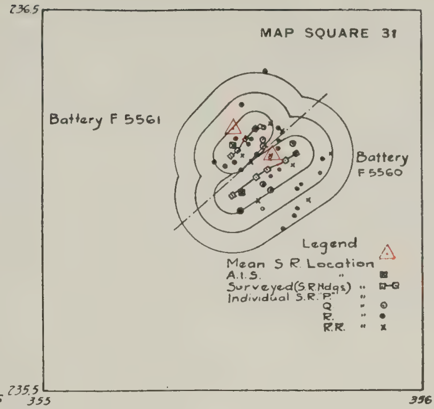

MAP SQUARE 27
236
235
353
354
Battery 3466
LEGEND
Mean S.R Location
A.I.S.
Surveyed
Individual S.R.P.
Q
R
RR

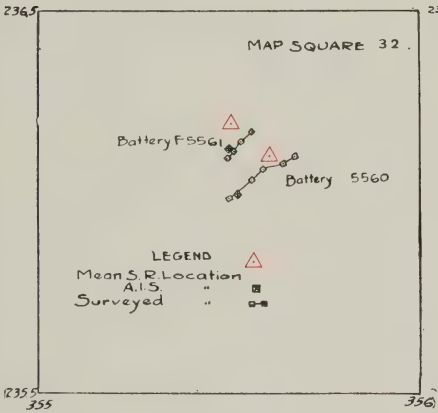

MAP SQUARE 28
236.5
235.5
354
355
LEGEND
Mean S.R. Location
A.I.S.
Surveyed
Individual S.R.P.
Q
R
RR
Battery F 4258
Battery F 4759

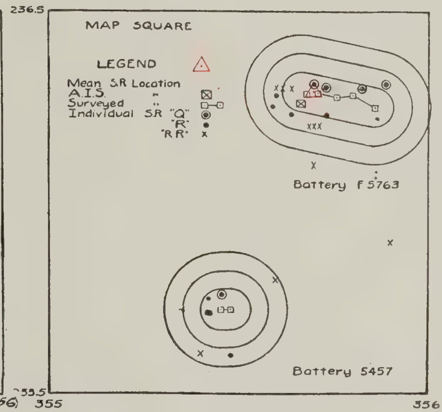

MAP SQUARE 29
237.5
236.5
354.5
355.5
Battery F4868
LEGEND
Mean S.R. Location
A.I.S.
Surveyed
Individual S.R.P.
Q
R
RR

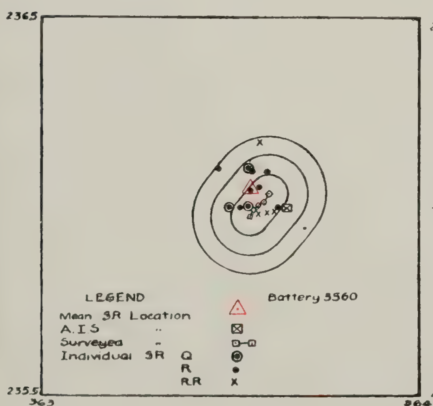

MAP SQUARE 30
237.5
236.5
355
356
Battery T 5369
Legend
Mean S.R Location
A.I.S.
Surveyed (S.R.Hdqs.) Location
Individual S.R.P.
Q
R
RR

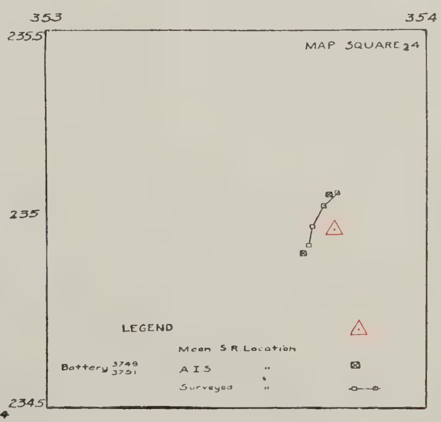

MAP SQUARE 31
Battery F5369
LEGEND
Mean S.R. Location
A.I.S. "
Surveyed "
237.5
236.5
355
356

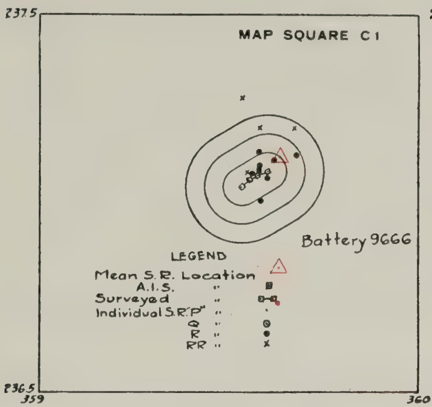

MAP SQUARE 31
Battery F 5561
Battery F 5560
Legend
Mean S R. Location
A.I.S. "
Surveyed (S.R.Hdqs) "
Individual S.R.P. "
Q "
R. "
R.R. "
236.5
235.5
355
356

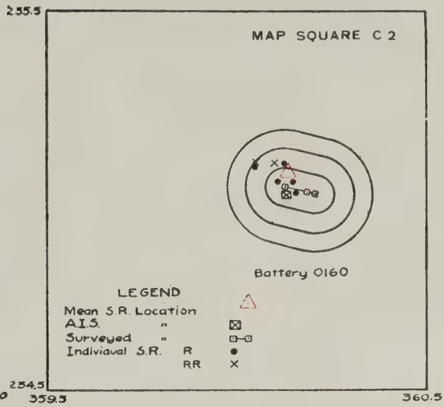

MAP SQUARE 32.
Battery F5561
Battery 5560
LEGEND
Mean S.R. Location
A.I.S. "
Surveyed "
236.5
235.5
355
356

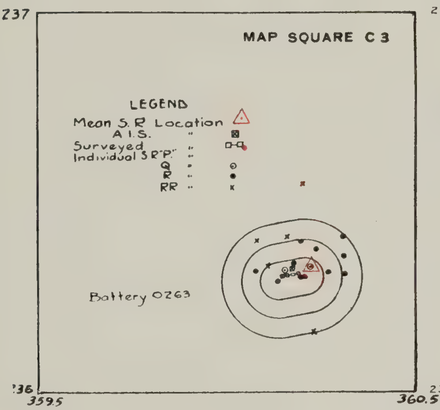

MAP SQUARE
LEGEND
Mean S.R Location
A.I.S. "
Surveyed "
Individual S.R "Q"
"R"
"R R"
Battery F 5763
Battery 5457
236.5
355
356

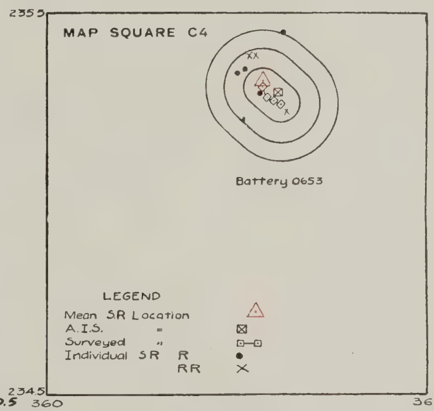

LEGEND
Battery 5560
Mean SR Location
A.I.S "
Surveyed "
Individual SR Q
R
RR
236.5
235.5

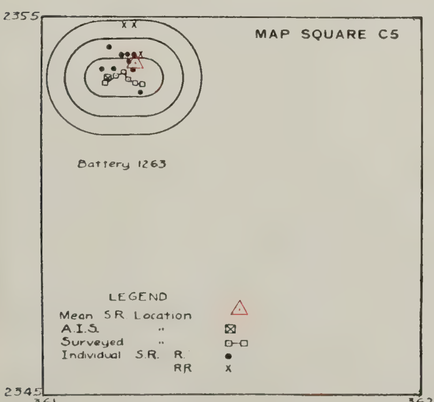

353
354
MAP SQUARE 24
235.5
235
234.5
LEGEND
Mean S R Location
Battery 3749 3751
A I S "
Surveyed "

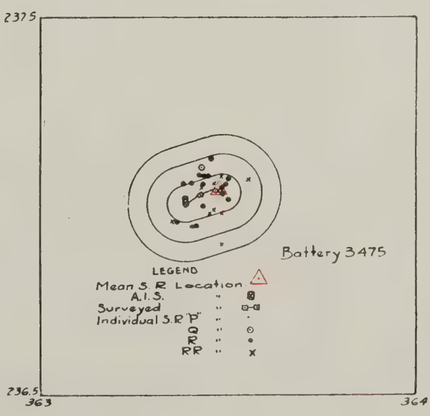

237.5
MAP SQUARE C1
Battery 9666
LEGEND
Mean S.R. Location
A.I.S. "
Surveyed "
Individual S.R."P" "
Q "
R "
RR "
236.5
359
360


235.5
MAP SQUARE C2
Battery 0160
LEGEND
Mean S.R. Location
A.I.S. "
Surveyed "
Individual S.R. R
RR
234.5
359.5
360.5


237
MAP SQUARE C3
LEGEND
Mean S.R. Location
A.I.S. "
Surveyed "
Individual S.R."P" "
Q "
R "
RR "
Battery 0263
236
359.5
360.5


235.5
MAP SQUARE C4
Battery 0653
LEGEND
Mean SR Location
A.I.S. "
Surveyed "
Individual SR R
RR
234.5
360
361


235.5
MAP SQUARE C5
Battery 1263
LEGEND
Mean SR Location
A.I.S. "
Surveyed "
Individual S.R. R
RR
234.5
361
362


237.5
Battery 3475
LEGEND
Mean S.R. Location
A.I.S. "
Surveyed "
Individual S.R."P" "
Q "
R "
RR "
236.5
363
364

Counter-battery. None on position—heavy accidental shelling nearby meant for 5556.

A.I.S. Coördinates. None.

Surveyed Coördinates, G-2-C. None.

	x	y
Coördinates from Map Detail........................	355 460	235 720
Mean S.R. Coördinates..............................	355 460	235 710

Remarks. Batteries 5556 and 5456 are made up of ten emplacements lying in a row from 355 455 to 355 600—these are all
235 625 235 670
completely ruined from age, and have not been used in several years —A.I.S., however, reported 5556 as active in the 30-day list, and 5456 as active in the 60-day list—during the entire period of operation S.R. reported 5556 once (July 19th) and 5456 not at all. The report on 5556 was a short, rated R, on the new position 5457—the flares from 5660 and 5457 were doubtlessly all ascribed very naturally to 5556 or 5456, as these showed up very clearly on the photographs—5457 was reported by S.R. 5 times—1 Q, 2 R's and 2 RR's, given as a 10.5 firing on Rambucourt and Beaumont, and as a 77 firing on Hamonville—board sign reading Art. Stell. 106 in position—Map square 33.

BATTERY 5966.

An impartial consideration of batteries in the Gargantua group must include mention of 5966—a battery of 15 cm. Howitzers, apparently used recently—these Howitzers were never detected in action by S.R. or by any other agency. It is the only battery which was not detected in the area.

The batteries here described in detail are selected from this group, as were also the ones taken from the Mont Sec group, as typical. Comparison of the results with those for the Mont Sec group will show the character to be the same for all. It is not, therefore, profitable to present a more bulky or comprehensive report. The two groups here studied are both from the area covered by S.R.S. 1.

It may in consequence be thought that the results shown represent an optimum since the base survey was accurately rechecked, the handling of the apparatus and the computation were continuously under competent direction, the batteries worked on were definitely emplaced and the results were numerous and spread over a period of some six months. This is true insofar as the mean

locations are concerned. Better results cannot be expected and ones much worse might sometimes be secured, depending on the quality of the personnel. The accuracy of the individual locations could, however, have been considerably improved by the use in the calculations of a scientifically determined wind and temperature such as result from the work of so-called "wind sections." The individual locations do not, therefore, represent the optimum obtainable by S.R. The weather errors, being accidental in character, will probably not affect the accuracy of the mean locations.

Results of the character obtained by this section can be duplicated by any section similarly manned and similarly installed on a fixed front for the length of time that S.R.S. No. 1 was in operation. The very high accuracies obtained by S.R.S. No. 1 down to the order of 10m. result from the averaging of determinations over a considerable period of time. A dependable P accuracy for a position requires seven to ten independent locations—that is, independent in the sense that they are determined under different weather conditions. This means that the battery must fire from one position for ten or more days. On a moving front these conditions do not obtain so that S.R. sections operating against a moving enemy cannot be expected to give mean results of the accuracy of those shown in this report. The individual determinations ought, however, to be as good as those shown so that one rated P could be depended on to be within 50m. of the gun firing.

GROUP 3—MORT MARE—EUVISIN.

This group was covered by Sound Ranging Section 3. The area contains a great number of batteries, so closely spaced, and so interspersed with transient positions, that it becomes very difficult to arrive at clean-cut results in analyzing the sound ranging locations made there. A few charts giving locations are appended to this report. These are sufficient to show that the results were essentially similar to those obtained by S.R.S. 1, although, because of a variety of reasons connected with operation, not on the whole of the same high accuracy.

The section made five hundred and forty locations distributed amongst the forty batteries shown on Map 4, attached hereto. The plates show the results obtained for seven batteries, F9666, G0160, G0653, G1263, G3475 and G3560. Detailed descriptive data are included hereunder for all of these batteries excepting 3475 and 3560.

BATTERY F9666.

Calibre. 150 How. from gun wads.

Protection. Deep emplacements of earth and stone, wood foundation. Overhead cover, camouflage, wire supporting branches. Four emplacements with complete connecting trench scheme providing leads to ammunition tunnels and bomb-proofs. The position is in the open and on the top of a steep bank.

Direction of Fire. Uncertain, roughly S.W.

Communications. No particular road along positions. Extremely poor approach. Guns pulled out to rear of emplacements. Narrow-gauge R.R. in draw 100 meters to rear.

Counter-battery. Moderate. Most severe over No. 4 emplacement.

	x	y
A.I.S. Coördinates, 9666	359 580	236 580
Surveyed Coördinates (G-2-C)	359 570	236 570
Mean S.R. Coördinates	359 600	236 615

Remarks. This battery was reported by S.R. eleven times with accuracies, 4RR's, 7R's. Given as firing on Seicheprey, Bois de Jury, Beaumont-Flirey road, as a howitzer calibre (?) and as a 10.5 howitzer. Last reported by S.R. July 21, 1918. All emplacements have appearance of recent occupancy. Gun wad appears still fresh and there is much of it.

Diagrams. The individual locations of this battery are shown on map square No. C1.

BATTERY G0160.

Calibre. 10.5 How., identified by gun wads found at three of the emplacements.

Protection. Four emplacements, earth covered with camouflage wire and evergreen branches. No foundation present. No dug-outs at emplacements but some in vicinity. Position in open on reverse gentle slope.

Direction of Fire. Uncertain, roughly S.

Communications. Field artillery road in rear.

Counter-battery. Slight.

	x	y
A.I.S. Coördinates, 0160	360 130	236 020
Surveyed Coördinates (G-2-C)	360 140	236 020
Mean S.R. Coördinates	360 115	236 065

Remarks. This battery was reported by S.R. seven times with accuracies, 2RR's, 5R's, firing on Beaumont; calibre 77. This cali-

bration may be correct due to the fact that 77 gun wads were found at the No. 1 emplacement, also from this emplacement wheel tracks showing it to be relatively more recently active than the others were found. Last reported August 8, 1918, by S.R.

Diagrams. The coördinates of the individual location of this battery are shown on the map square No. C2.

BATTERY G0263.

Calibre. 10.5 How., identified from wads; 77 gun, identified from ammunition.

Protection. Seven emplacements, four of which are concrete and steel, built in earth bank. The remaining three are open earth emplacements under cover of camouflage, wire and evergreen branches. Dug-outs in the concrete emplacements. The whole group lies in the open on a gentle, reverse slope.

Direction of Fire. About 10 degrees S.E.

Communications. Field artillery road to the rear with narrow-gauge RR. paralleling it.

Counter-battery. Entire region heavily shelled.

	x	y
A.I.S. Coördinates, 0263	360 175	236 325
Surveyed Coördinates (G-2-C)	360 170	236 310
Mean S.R. Coördinates	360 200	236 335

Remarks. This battery was reported by S.R. 17 times with accuracies, 4 RR's, 11 R's, 2 Q's, given as a 77 and 10.5 Howitzer, firing on Beaumont and Bernecourt, Hazelle, Jury, Remieres Bois, and east of Flirey. Last reported by S.R. on September 3, 1918. No. 3 of the concrete group appeared to be the only one of that group recently active. In earth emplacements there were many empty shell cases and in front, fresh wads showing recent activity and 77 calibre.

Diagrams. The coördinates of the individual locations of this battery are shown on map square C3.

BATTERY G0653.

Calibre. 10.5 Howitzer.

Protection. Four earth emplacements covered with camouflage of wire and branches. Trenches connecting emplacements, earth and rock dugouts to the rear. Located on the front edge of a low bush area. No. 4 pit at top of slope.

Direction of Fire. Approximately south.

Communications. Two hundred meters to good road. Guns pulled out front.

Counter-battery. Heavy.

	x	y
A.I.S. Coördinates, 0653	360 600	235 290
Surveyed Coördinates (G-2-C)	360 590	235 280
Mean S.R. Coördinates	360 550	235 330

Remarks. This battery was reported by S.R. eight times with accuracies of 3 RR's and 5 R's. It was given as a 10.5 Howitzer firing upon Flirey, Bois de Jury and west of Bernecourt. It was last reported September 3, 1918. All emplacements show signs of recent construction.

Diagrams. The coördinates of the individual locations of this battery are shown on map square C4.

BATTERY G1263 AA.

Calibre. 77, identified by wads.

Protection. Three emplacements, very good condition, circular in form, earth and rubble masonry; center pedestal concrete with circular mounted on it, graduated from 0 to 640. Good dugouts near position. This battery lies practically in open, except for a few straggling trees on gentle reverse slope.

Communications. Good artillery road in rear.

Counter-battery. Slight.

	x	y
A.I.S. Coördinates, 1263	361 175	236 335
Surveyed Coördinates (G-2-C)	361 190	236 340
Mean S.R. Coördinates	361 220	236 380

Remarks. This battery was reported by S.R. 12 times with accuracies of 9 R's and 3 RR's, given as an anti-aircraft.

Diagrams. The coördinates of the individual locations of this battery are shown on map square C5.

BATTERY 3560.

Calibre. 77.

Protection. Five concrete emplacements—roofs of concrete and iron.

BATTERY 3475.

Calibre. 77.

Protection. Four earth emplacements—camouflaged.

GENERAL REMARKS.

The detailed examination which was made of these areas brought out certain facts of general interest concerning the enemy's habits in handling artillery. It seemed, for example, as if in recent months he had come to employ those battery positions which were subjected to our counter-battery only transiently. He made no attempt to protect his new emplacements, preferring to withdraw his guns after a certain period of use. To this end, the emplacements were set near roads, and were so constructed that the guns could be pulled out by horses. In cases where older concreted emplacements which were difficult of egress existed on the site, these were abandoned, and new open ones, without any protection, were constructed in front of, or beside the old ones. Batteries F0947, F5457 and G0263 are excellent examples of this practise. All the heavily concreted emplacements were old, probably of date 1915-1916, and, without exception, abandoned for open emplacements nearby. The effects of 24 cm., or even 15.5 cm. fire on the concreted emplacements were very destructive in case hits with delayed action were made close beside them, but not otherwise. Some heavy counter-battery work was carried out without injuring the emplacements fired at seriously. The great majority of these batteries were located in the forward edges of woods.

In addition to these emplacements which apparently were permanently occupied, unless fired upon, there were many surveyed transient positions staked out and marked "surveyed" which differed from the others in not having wooden gun platforms, and in being without any housing accommodations for gun crews—*e. g.*, F5457 (new), F5369 and G1465. These positions were evidently repeatedly occupied.

There were also numerous unsurveyed transient positions, doubtlessly used during raids. The fields near the Etang le Bailly and also those in the neighborhood of G1465 contained evidence of the general use of artillery in all parts.

Finally, positions were taken up almost any place where there was suitable defilade on the extensive narrow-gauge railway system which served all parts of the area.

The enemy, making use of his railways through Thiaucourt, could easily get an enormous weight of artillery into action on very short notice without any large amount of preliminary work in preparing emplacements. His main attempt in recent months was

unquestionably to obtain mobility and flexibility of artillery disposition rather than to attempt to protect his pieces in known, permanent positions.

NOTE: The data given in the three groups covered by this report were collected and compiled by Capt. C. B. Bazzoni, Engineers, U. S. A., who was in charge of the sound ranging sections during their operation on the front. The plates were prepared under his direction. He is thoroughly familiar with the antecedents of all data presented, and guarantees their honesty and general accuracy.

ANTI-TANK DEFENSES.

TANK DITCH.

The ditch illustrated herewith has been suggested by the British. They claim it provides an effective barrier for tanks. The earth is best thrown on the side remote from the enemy, but if necessary can be scattered so as not to obscure the view from fire trenches. In this case the ditch might be camouflaged.

Tanks are a very efficient weapon against machine guns, and it might be well to consider surrounding machine-gun nests with some sort of ditch, similar to the one shown. A tank once stalled in a ditch of this character would be very difficult to extricate under fire. It would be well to destroy by shell-fire any tank thus stalled, as otherwise the ditch could be used by the crew as cover from which to continue an attack.

GERMAN ANTI-TANK MINE.[1]

This mine consists of a wooden box, 8 by 12 inches and 2 inches deep, all inside measurements, with a tin cover. On the top of the box is a firing bar with four legs secured as described below and also by wire not shown in the sketch. The mine is painted and camouflaged to suit the ground. It can be either laid out beforehand or thrown when required by means of a handle. It weighs about 12 pounds and contains 7½ pounds of explosive.

Firing arrangement. The firing arrangement consists of four spring percussion lighters, of the usual type; that is, they are fired on the withdrawal of a safety pin. They are connected by instantaneous fuse to detonators.

The firing bar has attached to it two metal triangles, on the lower edge of which are two studs which, when the bar is placed in position, fit into the rings in the head of the safety pins of the percussion lighters, through holes in the tin covering, on the sides of the bar. This tin cover acts as a safety cover to the lighters. When

[1] German measures against tanks. From A. E. F. Ordnance Bulletin of August 24, 1918.

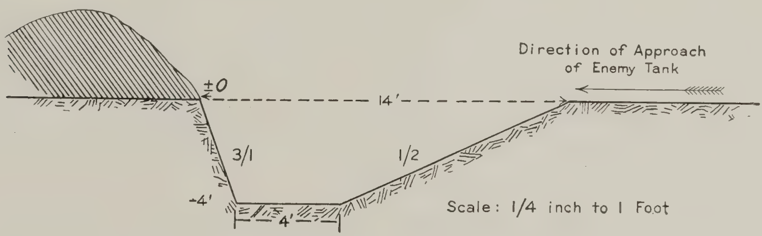
a weight passes over the firing bar, the safety pins of one or more of the lighters are drawn and the mine fires.

Sensitiveness. It is stated that the mines when ready for use can be handled without danger. They have been thrown about with impunity. They are not sensitive to blows and only fire when a heavy weight presses on them. A 9-cwt. roller run over a mine fired it.

To render harmless. Unfasten the wire (if any) securing the firing bar and unscrew the wing-nut. Then carefully remove the bar by withdrawing first one and then the other of the two metal triangles on it from contact with the percussion lighters. The lighters can be removed by unscrewing the staples which hold them in position.

Anti-Tank Defense.

In the course of the attack of August 8 we captured a number of interesting documents which show the German opinion in re-



gard to the question which is greatly preoccupying the command: the defense against tanks.

Particular attention is called to the following points:

1. The artillery sections assigned for anti-tank defense;
2. The anti-tank rifles;
3. The tank mines.

Organization of Anti-Tank Defense.

In the organization of the anti-tank defense, the fact should be taken into consideration that water courses, stretches of marshy ground and woods constitute obstacles for tanks. The distribution of the defensive arms of the service should be regulated in accordance with this consideration.

It is absolutely necessary even when the situation is quiet that all the arms suitable for anti-tank defense be distributed in depth and always ready to engage in action.

The logical cooperation of the various arms must be assured.

1. *Artillery.* It is well to prepare the anti-tank defense in such a manner that the greatest possible number of guns, distributed in depth, may participate in it.

A distinction must be made between:

(*a*) The anti-tank guns, which, being distributed in depth between the main line of resistance and the artillery zone, are only used for anti-tank defense.

They must dominate the zone through which the tanks may advance with direct fire. Their number will depend upon condition. The importance of anti-tank combat will offset the withdrawal of these guns from barrage fire and other missions.

An ammunition supply of 250 to 300 rounds will be sufficient for these guns. A shortage of steel-pointed shells may be made up by 150-mm. shells; other shells may likewise be used in case of necessity.

(*b*) Artillery sections assigned to anti-tank defense. Each division designates an anti-tank section from the field artillery out of the line and at rest. This anti-tank section will be provided with horses and held in readiness in case of "urgent" alert.

The limbers will be supplied with steel-pointed shells. The guns will be followed by two caissons, which will carry shrapnel in addition to the steel-pointed shells.

Numerous firing positions, with a view to bringing these sections into positions, even including the advanced infantry zone, should be reconnoitered. It is unnecessary to establish ammunition dumps at these positions, as ammunition caissons will be brought up.

(*c*) *Guns in position.* They will go into action, using direct fire, against the tanks which break through (field guns, light howitzers and heavy field howitzers). The use of a rather large number of these guns should be provided for. When they cannot fulfill their mission from their positions, steps will be taken to withdraw them promptly from their shelters. Frequent exercises will be held in order to make sure that they will be ready to open fire rapidly against tanks which have broken through. The proper supply of ammunition will be kept in readiness.

(*d*) Heavy batteries, whose opportunities for observation are especially favorable for combating tanks which have penetrated our lines.

For these batteries, the terrain will be divided into zones for the purpose of anti-tank combat. The range to certain important points will be determined in advance and communicated to the artillery men.

2. *Heavy machine guns.* As a rule, all heavy machine guns, even those held in reserve, will be supplied with armor-piercing cartridges. The primary mission of each heavy machine gun is to combat tanks which penetrate into its zone, and it must be fully aware of this responsibility. Machine guns placed at points especially favorable to penetration by tanks must know that they have a very special responsibility. For this reason they will be designated by the name "Anti-tank machine guns."

3. *Anti-tank rifles* will generally be placed in the main line of resistance or a short distance behind this line. Their short range (maximum, 500 meters) will be taken into consideration.

4. *Trench mortars.* The light trench mortars, echeloned in depth and engaged in groups of at least two each, will be distributed in the infantry zone according to the principles applying to machine guns. Anti-tank combat will also be their permanent mission. When they are assigned barrage missions, it will be necessary to reconcile this mission with the anti-tank defense.

The light trench mortars placed at points favorable to penetration by tanks will be called "Anti-tank trench mortars."

The medium and heavy trench mortars may also frequently intervene effectively in anti-tank combat.

5. *Anti-tank mines.* They complete the action of the other arms in anti-tank defense. They are best placed first of all in the outpost zone and then in sufficient number in the strong points of the intermediate zone and in the support positions. The troops will be trained in their use and will be taught to employ concentrated charges in anti-tank combat. When the tanks attack, all the arms suitable for the purpose must consider anti-tank combat their only mission until the last tank has been destroyed. If the tanks are destroyed by fire, the entire attack fails. This fact must be known by all troops.

(Signed) VON HOFACKER.

Conduct of the Infantry Fighting in Conjunction with Tanks.

The mission of the tanks is obviously the same as that of the batteries acompanying the infantry. It consists:

(*a*) In neutralizing the enemy's supporting points, machine-gun nests, and other centers of resistance.

(*b*) In assisting the infantry to repulse hostile counter-attacks.

The rapid exploitation by the infantry of the effect produced by tanks is a decisive condition for success. The situation on the battlefield indicates whether the infantry must precede, accompany or follow the tanks.

In an attack on close objectives, the infantry and tanks advance side by side in close liaison.

For more distant objectives, the speed of the tanks does not permit them to keep up with the infantry. In this case, the infantry must not stop because the tanks can not keep up, but must execute its mission as rapidly as possible without regard for the progess of the tanks.

If the infantry is stopped by hostile centers of resistance, the tanks will charge them, in advance of the infantry lines, in order to neutralize them. Positions, which the infantry is unable to overcome (for example, machine-gun nests on counter-slopes), or which had not previously been located (for example, those suddenly discovered on the flank), will be put out of action by the rapid intervention of the tanks. The infantry must follow immediately behind. It is impossible for the tanks alone to hold ground which they have gained.

To repulse a counter-attack, the tanks immediately enter the battle from wherever they happen to be and direct their attack especially towards any breaches which may develop in the enemy's ranks. Their coöperation with infantry counter-attack is thus best assured.

It is of great importance that the liaison between the infantry and the tanks be close and that the commanders of the two forces hold personal conferences during the battle.

In case a tank breaks down, the crew will participate in the battle as an assault detachment with machine-guns, hand-grenades and carbines.

(Signed) LUDENDORFF.

German Anti-Tank Artillery.

The following document is another proof of the excellent results obtained by our tanks; it shows how much the Germans fear their attacks. An order captured some time ago prescribed that in case

of a tank attack "all arms capable of combating them must consider this their only mission until the last tank is destroyed."

According to a communication to the IId and XVIIIth Armies in the course of the recent fighting, tanks have broken through in great numbers along narrow fronts and, continuing straight ahead, have immediately attacked the battery positions and division headquarters. At several points, it seems to have been impossible to organize a defense in time owing to the fact that the batteries, having their guns dug in, were not mobile enough and were not ready to fire in time to defend themselves quickly against the tanks which were attacking from all directions. The anti-tank defense must be developed upon the basis of these experiences. For the artillery in particular, regulations must be provided analogous to those which are in force against cavalry attacks.

For this purpose it is necessary:

1. To establish a direct anti-tank observation post functioning day and night in the vicinity of each battery;

2. To avoid digging the guns in too deeply. It is sufficient that the men be protected;

3. To dispose all guns, at least those of small and medium caliber, so that they may be able to withdraw from their positions in a few seconds, and without difficulty execute direct fire in all directions, including the rear. The guns must be ready to fire at all times. The protection of heavy batteries and very large-caliber guns requires special measure (for example, placing them under the protection of light and medium batteries in position near by; designate special anti-tank sections).

4. To increase the number of mobile anti-tank sections, to employ the mobile artillery anti-tank reserves by bringing them up quickly, placing them in position in the open and opening fire without delay; by making speedy arrangements which will permit the teams of all the batteries to be quickly brought up.

5. To provide all the machine gun batteries with armor-piercing cartridges.

NOTICE: ON MINE AGAINST TANKS.[1]

Nature of Device.

The mine consists of a 75-mm. H. E. shell armed with a special fuze, and placed in a cubical wooden box whose sheet-iron lid, descending as the tank passes, detonates the shell.

[1] (From the French.)

Fuze.

The special fuze is a special percussion detonating 24/31 made up of:

1. *A fuze body* IA shortened, with socket and 2g. primers;
2. *A fuze head* IA regulation, except that one spiral and the two semi-rings are replaced by a *safety ring* of model of the IT fuze;
3. *A primer carrier* assembled in a delay carrier;
4. *A delay carrier;*
5. A protecting cap of sheet iron.

The tightness of the joints is obtained by thin disks isolating the sensitive parts of the apparatus.

A tin hood covers the head of the fuze.

A tin washer is interposed between the head of the booster and the fuze and in addition, a coat of copal paint is spread on the joint of the booster and the fuze hole of the shell.

Functioning. The percussion apparatus of the fuze consists of a *firing pin* held by a steel *pin.*

Under a static force of 350 to 400 Klg. the pin shears and the firing pin, set free, causes the ignition of the primer of the relay.

Box.

The box is of wood, 26 mm. thick. It is cubical, 300 mm. on one side. Two strips, notched for the shell body and intended to hold the shell upright, are nailed on the inside of the box, one on the bottom and the other at the height of the shoulder of the ogive.

A lid of sheet iron, 4 mm. thick, slightly rounded, is riveted on two angle-irons of 30 mm. and 30 mm., forming hinges with two similar angle-irons bolted on one of the walls of the chest.

The upper edges of the chest are beveled toward the exterior and faced with a band of flat iron so as to prevent pebbles getting in between the lid and the edges of the chest and preventing closing.

Method of Use.

Putting Mine in Position—

The box is buried, the hinge parallel to the bottom, so as to form a slight projection of 2 to 3 cm. above the ground.

In a terrain with a mean amount of argillaceous material, the surface of the bottom of the box is sufficient to prevent its becoming

buried under the passage of a tank and consequently sufficient to cause with certainty the functioning of the mine; but on soft terrain, in the bottom of the hole, for the box, there should be arranged such material as planks, wood or stones.

The box being put in place, and kept open, the fuze is screwed on the shell in such a way as to make the joint tight.

The shell is placed upright in the box between the supporting strips, then the tin hood and the safety ring are removed.

The fuze is covered with its protection cap which is to prevent earth from getting under the head of the firing pin, which might prevent the functioning of the device.

The lid is lowered carefully and rests on the head of the fuze. The box is then covered with a light layer of earth, so as to hide it completely.

Removing the Mine—

Free the lid from the box, raise it up, remove the protection cap and put under the head of the firing pin a safety ring. The shell can then be handled without danger.

If it is desired to make the mine temporarily harmless, without raising it, leave the shell in place, put the safety ring in the fuze and cover it with a tin hood, or remove the fuze.

Tactical Use—

With 2,000 shells per kilometer, there can be formed an impenetrable barrage.

Arrange the line of mines in places inaccessible to ordinary vehicles and horses. The most suitable places are among the outside edge of imperfect obstacles, such as felled trees, creeks, trenches, invisible wire entanglements, and at some distance from the obstacles.

These lines should be carefully marked on special directing maps.

Under the passage of a tank, even when the caterpillar band only covers the mine lid by a few centimeters, the mine functions.

The fuze is provided with a slight delay of one-tenth of a second, which allows the device to function when the tank is well over the box.

VOLCANIC TUFF AND ITS USES.[1]

INTRODUCTION.

The engineering and industrial uses of Tuff, though practiced in some of its forms for centuries, is seldom given much thought by American engineers engaged in American enterprises. American text-books on concrete, for instance, make brief and passing introductory mention of the fact that Puzzolan Cement, or Puzzolana, was known and used by the Romans and their contemporaries centuries ago, and leave us to believe that its general disuse followed the advent of Portland Cement. Now we find ourselves in and near a considerable district, one of whose principal industries is the quarrying of volcanic tuff and the milling and marketing of pulverized Trasstuff for use in mortar and concrete.

The words "Tuff" and "Tufa" have been rather loosely and interchangeably used, but the best and most modern authorities make a clear-cut distinction. Tufa is now restricted to use as a designation for the porous calcareous deposits built up relatively rapidly by springs or other waters heavily charged with minerals. Tuff, on the other hand, in its best use, indicates a rock of volcanic origin, and it is Tuff, not Tufa with which this paper is concerned.

Tuff may be defined as finely divided rock débris hurled explosively from a volcanic orifice. These deposits have lain for thousands of years and have been more or less hardened into rock by pressure and by infiltration of water—in some cases, loose ash-like beds, unpetrified, are found. In some cases Tuff occurs, having hardened under water, and in others fossils may be found.

The fragments thrown off by a volcano naturally grade themselves on falling, the smaller particles being carried further and being more influenced by the wind. Geologists have arbitrarily classified these fragments; those from the size of an apple and up are called Bombs, those the size of a nut are called Lapilli, and those the size of a pea or smaller take the name of Ash. Rock formed from the largest is called Agglomerate; from fragments in the

[1]Substance of a lecture delivered before Officers Schools, 301st Engineers, by Captain A. L. Shaw on April 4, 1919, at Brohl-am-Rhine, Germany.

Lapilli class, Breccia; and Tuff is derived from the Ash class. The explosive action of steam, and the ash-like properties of the débris, account for the vesicular nature or porosity of this class of stone.

Being a metamorphic rock, it may be expected that Tuff of widely varying mineral composition will occur, depending on the nature of the older rock formations which furnished the material. The special name applied to a particular Tuff usually indicates its derivation from some particular kind of rock. The deposits in the Laacher Lake district and the foothills of the Eifel Mountains contain two principal and distinct types—Leucituff and Trasstuff, the

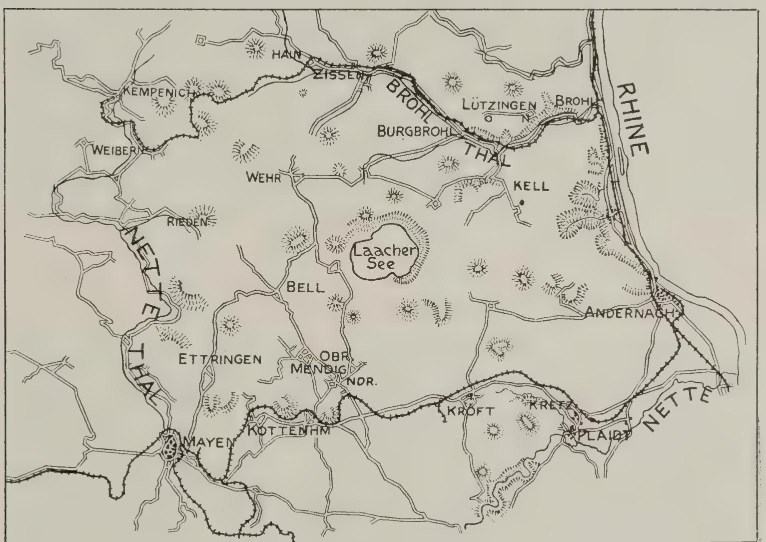


Fig. 1.

latter possessing the chemical properties essential to the production of Puzzolan cement, the former not at all.

Leucituff. Leucituff is so called on account of its principal mineral content—Potassium-Aluminum Silicate, called Leucite. The principal deposits of Leucituff are near Bell, Weibern, Rieden, Kempenich, Ettringen, etc., in the foothills of the Eifel and it is probable that they all originated from a group of volcanic orifices in the Eifel Range. It is extensively used as a building stone, being soft and easily shaped and carved and possessing a resistance to weather not unlike that of sandstone. That Tuff is quarried near Bell, is also called Bellu Backofenstein, and offers particularly high

resistance to heat. It is much used in walling up bake-ovens and for fire-brick. Most of the quarrying of this stone is done by hand, and in many instances lone individuals operate small workings and laboriously carve out blocks of the Bell stone with primitive tools into the shapes used for fire-brick.

The use of Leucite dates back at least to the middle ages, and many buildings old and new may be found constructed of it. Prominent in this vicinity are the parish church in Andernach, the abbey church at Maria Laach (11th and 12th Centuries), the Cathedral at Bonn, the Post Office and Handel high school in Cologne. It is able to compete in distant cities in spite of freight rates, and is used as far away as Berlin.

Leucituff was at first quarried entirely by hand methods, large blocks being laboriously split off and then cut up into sizes appropriate for the work in hand. Now, compressed air and modern drills and channelling machines reduce the labor and speed production. In 1914, there were about 140 quarries in operation and 1,200 workmen were employed in the production of Leucituff.

Trasstuff. Trasstuff is perhaps the most interesting of the two principal varieties, for, as has been already intimated, it is akin to the natural puzzolana which owes its name to the old Roman place of a similar name near Naples. Italy, Greece and Germany possess the three principal deposits of rock possessing Puzzolan qualities. The word "Trass" is remotely derived from the Latin *Terragium,* "a piling-up of earth," and suggest its origin from the dynamic forces of Vulcanism.

The principal and purest deposits of Trasstuff are found in the Nette Valley near the villages of Plaidt, Kretz and Kruft. The deposits in the Brohl Valley, while formerly of importance are now almost exhausted, most of the remaining plants there being limited to operation of the so-called "wild" or "mountain trass" beds which are more or less adulterated with the earths and whose product are inferior to pure trass in cementing qualities. An important use has been found for this "bergtrass," however, as a flux in glass and porcelain manufacture, due no doubt to its silicious content, and considerable quantities are shipped away for this purpose. All these trasstuff deposits doubtless owe their origin to the single great crater which is now the basin of the beautiful Laacher See.

The puzzolan principle manifests itself in the quality which

Fig. 2. Backofenstein Quarry, near Bell.

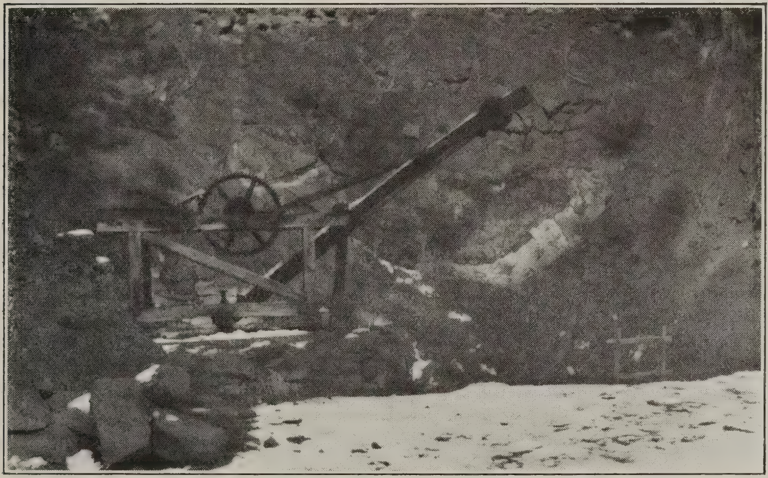


Fig. 3. ''One-Man'' Backofenstein Quarry, near Bell.

Trasstuff possesses of hardening, even under salt water, when pulverized and mixed with lime and sand. Its use thus in hydraulic mortar and concrete comprises the chief value of Trass. This phenomenon is accounted for by the presence in relatively large quantities in Trass of soluble silicic acid, which unites with lime to form insoluble calcium silicates.

The Romans brought the art of using Puzzolan with them when they occupied the Rhinelands and they mixed Trasstuff—using it not only for making mortar, but for buildings and tombstones. They conducted their operations in shafts and galleries and never went below the ground-water level for lack of pumping facilities. Many of these ancient galleries may still be seen in the cliff faces of the more modern open quarries.

The art seems to have been unused from Roman times until the middle ages. Early in the 16th Century, a Dutchman, Bernhard von Santen, built the first Trass mill not far from Brohl am Rhein and, once resumed, the use of Trass in lime mortar increased very rapidly. It remained for a comparatively recent investigator named Michaelis to discover its value in neutralizing the free lime in Portland cement, thus making possible the safe use of the latter in salt water without special precautions to assure the use of a cement with no excess of lime.

In the modern open quarries, large pieces are shaken down by the use of black powder or other explosive, and then broken up with hammers into pieces of about one-third cubic foot. Narrow-gauge railroads operated by cable or horses convey these pieces to the storage yards where they are stacked into the extremely ship-shape and uniform piles, or "Arken," where much of the natural moisture dries out. From one to two years or more is devoted to this stage, depending on conditions of weather and the demand for Trass.

The process of milling the Trass shows a variety of practice, and occasionally shipments of the rocks go direct from the "Arken" to the user who prefers to do his own grinding, having grinding as well as mortar or concrete mixing machinery on the job. The modern Trass mill first runs the stones from the "Arken" through a stone-crusher, quite similar to the type usually seen in the United States. It has two corrugated-steel jaws, one fixed and the other rocked by a toggle mechanism, and these jaws are set to pass pieces the size of the fist or a trifle smaller. From the crusher the crushed pieces go by gravity or conveyor to a "Ball Mill," or rotating

Fig. 4. The Man and a Pile of Hand-made ''Fire-Brick.''

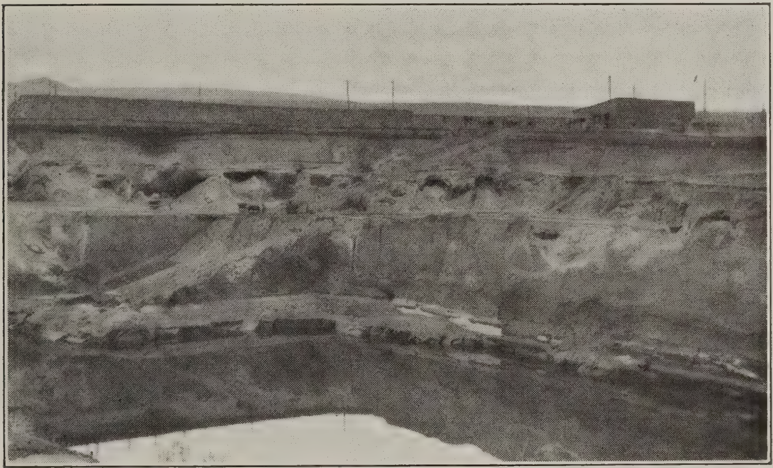


Fig. 5. Trass Quarry in Nette Valley.

cylinder of perforated steel containing iron balls, about 4 or 5 inches in diameter, which pulverize the Tuff by abrasion, the fine material dropping through the perforations of the cylinder onto an outer cylinder, or screen, of wire mesh, with from 30 to 35 meshes to the inch. Through this the powdered Trass must pass before it reaches the chutes leading it to the bagging or storage bins. Prime movers are generally steam-driven.

An occasional mill may still be found where the stones are taken from the ''Arken'' pounded to 2 or 3-inch pieces by hand and ground between old-fashioned millstones actuated by water power, with sometimes an intermediate drying on heated steel plates.

It is estimated that, before the war, several million hundredweight of Trass were shipped, though this seems a large output for the 34 quarries and 700 employes then engaged. Light railways and cable-operated ''skips,'' however, reduce the number of men needed as compared with former methods. Before the war the cost varied from 15 to 20 cents per 100 pounds, or 60 per cent to 80 per cent as much as Portland cement in the United States at the lowest price it reached during the years immediately preceding the war.

It is an interesting fact to note that Trass alone is inert, and takes no harm from water or moisture as does cement. This fact considerably simplifies its storage and handling. When moist, it is, however, more difficult to obtain an intimate mixture with the other ingredients of an aggregate.

To go more minutely into the practical uses of Trass for building purposes, its use with lime mortar and with cement mortar or concrete will be separately considered. It must be confessed at the outset that many of the conclusions which follow have been necessarily reached in a rather one-sided manner. The writer has been restricted in his research first to visits in quarries and mills where, naturally, enthusiasm for the product is found; and second, to book references of an advertising nature which, if their authors at all resemble American advertisers, lose no chance to display the advantages of Tuff, overlooking if not concealing any disadvantages it may have.

Trass with Lime. Used with lime and sand, Trass imparts to the mixture the quality of induration which ordinary lime mortar so notably lacks. As is well known, lime mortar requires carbon-dioxide from the atmosphere to complete the process of setting, and this quality makes hardening in the center of the mass a slow process,

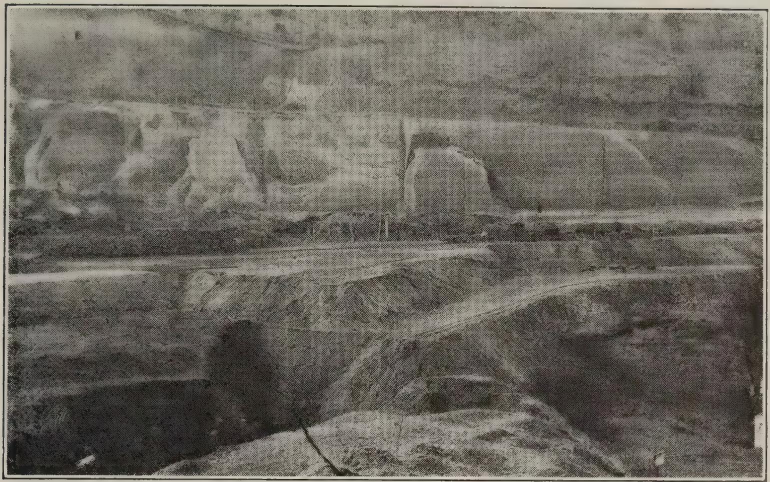


Fig. 6. Trass Quarry near Tonistein in the Brohl Valley.

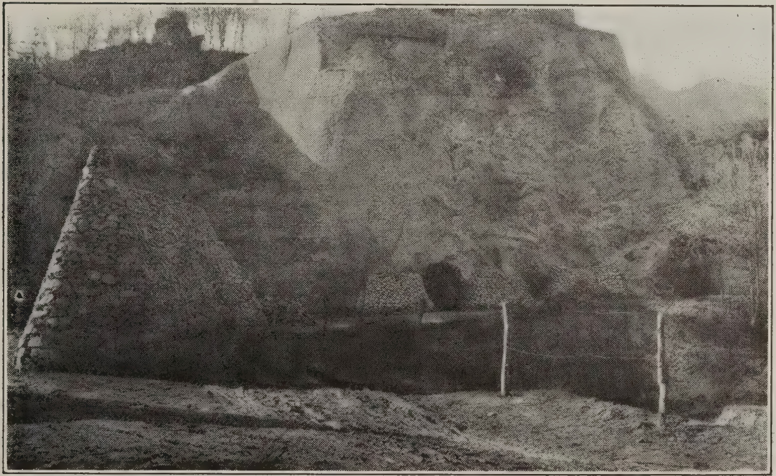


Fig. 7. Arken, or Drying Piles, in Brohltal. Tunnel follows a vein of marketable Trass in this otherwise abandoned quarry.

and precludes the use of that sort of mortar under water. The presence of free silicic acid in the Trass alters the nature of the chemical reactions, so that, in lime mortar, calcium silicates instead of carbonates are formed, and the change takes place as readily under water as in air. The resulting mortar is more dense and more elastic, exhibiting more the characteristics of cement mortar, though falling short of the strength of the latter.

The effects of frost are claimed to be non-injurious, the only result being a delayed hardening process. The outer surfaces, however, are apt to scale-off as with cement concrete, so that where appearance is a factor, freezing before setting should be avoided.

Setting is not as rapid as in lime or cement mortar but is long continued, the mass gaining strength over long periods and never seeming to reach that point beyond which deterioration commences. The mortar in some of Europe's ancient buildings, still stone-like and firm, bears witness to this property of trass-lime mortar. In modern practice it is not uncommon to add varying amounts of Portland cement to increase the speed of setting. Proportions, by volume, between the limits, 1 Trass : 1 lime : 1 sand, and 1 Trass : 3 lime : 5 sand are commonly used, the richer the mixtures for hydraulic construction and the leaner in ordinary building walls and the like.

It is customary to first mix lime and Trass dry, then add sand and mix dry, finally adding water, using a minimum of the latter, as an excess tends to wash the aggregate and destroy the homogeneity of the mass. Slacked lime, in paste or powdered form, is used and it is important that the slacking be complete and thorough before use, at least five days being allowed to elapse after slacking to insure that all particles have been reached by the slacking action. In salt-water operations care must also be taken to avoid an excess of lime which is attacked by sea water.

The dikes of Holland, many of which are centuries old, were constructed with the Trass-lime mortar, and many of the sea walls, dry docks and other labor works erected by the German Naval Administration bear witness to its efficacy.

Lime-trass mortar possesses to a considerable degree resistance to heat, and is much used for cementing fire-brick. There is also claimed for it the property of readily and perfectly bonding on surfaces already set.

Trass with Portland Cement. Ordinary commercial cement almost invariably contains an appreciable excess of lime, and to be

sure of a cement suitable for use in sea water special specifications must be used, at consequent added cost of money and time. If the ordinary cement is used, the chlorides and sulphates of sea water gradually penetrate the pores of the concrete and attack this lime, setting into motion complicated chemical reactions which result in the eventual disintegration of the mass. This tendency is sometimes overcome by the use of carefully proportioned and graded aggregates which increase the density and reduce the voids, thus preventing the entrance of the sea water.

The advocates of the use of Trass for hydraulic mortar or concrete claim that it not only blocks the attack on the lime by con-

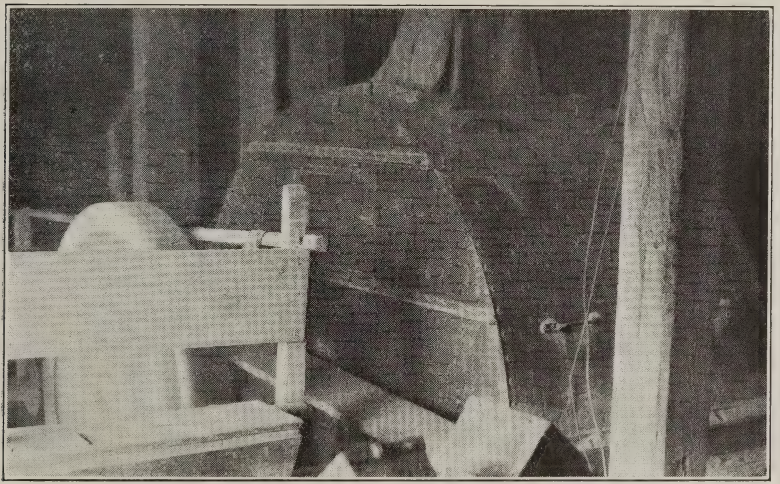


Fig. 8. "Ball Mill" in which Trass is pulverized.

verting it into the more stable silicates, but also increases the density of the mass by the introduction of this extra material of a fine nature which tends to reduce voids.

Many proportions for Portland cement and Trass are used, ranging between wide limits. Mortar varies from 1 cement : 1 Trass : 2 sand to 1 : 1 : 4; and concrete from 1 cement : 1 trass : 2 sand : 4 gravel to 1 : 1 : 4 : 9. The richer proportions are, of course, those used for hydraulic projects. The results of a few tests have been plotted, involving the use of trass in Portland cement mortar and concrete. The records of these tests give no indication of the quality of Portland cement used, nor do they indicate a high or a low free lime content. The conclusions reached must be, therefore,

merely relative, and it will be well to disregard the actual numerical values. These tests do show, however, that under certain circumstances certain results may be expected, and they may therefore be of value.

Tensile tests of mortar or concrete are chiefly valuable in indicating elasticity and toughness. Figs. 9 and 10 would appear to prove the contentions of the advocates of trass with regard to its tendency to increase elasticity. Fig. 9 shows that by replacing with trass part of the cement in 1 : 2 mortar, the strength, when mixed with fresh water, is slightly decreased; when salt water is used, however, the trass-cement mortar is much the stronger. The effect of gauging with sea water noticeably decreases the strength of the cement mortar, while the trass-cement mortar seems to give better results with salt than with fresh water. The slower initial setting and the longer continued increase of strength is indicated by these and the curves in Fig. 10.

Fig. 10, showing tests of specimens allowed to harden in sea water, plainly shows the loss of strength of the cement mortar during the interval between 3 and 12 months, suggesting that deterioration has begun, due to the attacks of the harmful elements of salt water. The two curves of tests with trass replacing portions of the cement do not show this deterioration. As between the two trass curves, that using 1 part cement and 1 part trass seems to be the best suited to neutralize the excess of lime in the particular cement used. This suggests the necessity, in using trass, of frequent tests to check up the lime content in the cement, with a view to varying the per cent of trass to properly neutralize it without undue excess of trass.

Compressive tests are, of course, the most valuable as indicating the true practical strength of mortar or concrete. Fig. 11 shows tests of a cement mortar and of a mortar with half the cement replaced with trass. It shows that the cement mortar is the stronger, but the trass-cement mortar curve lies but a small distance below it. This suggests the possible economy of the use of trass, due to its cheaper cost and the apparent feasibility of investing the saving in additional cement to give equivalent strength while maintaining the advantage of having neutralized excess lime with trass. There should be further emphasized the importance of using just sufficient trass (or a slight excess for safety) to account for whatever free lime may exist in the particular cement in question. Beyond this

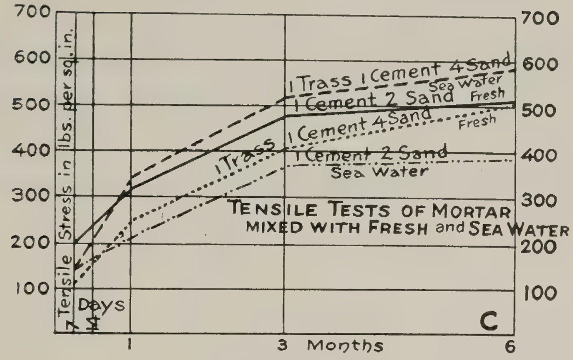


Fig. 9.

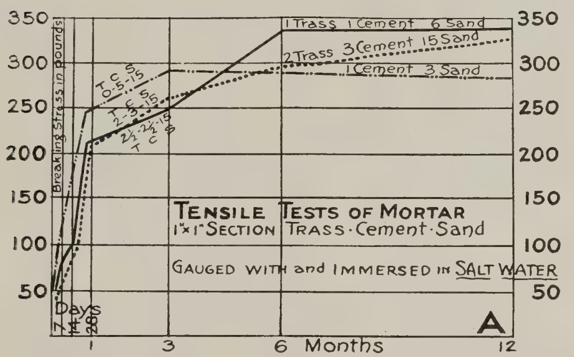


Fig. 10.

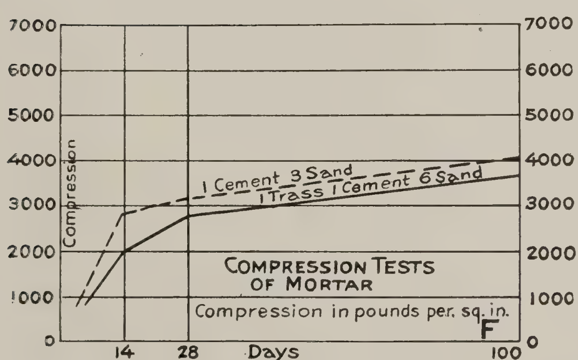


Fig. 11.

point the addition of trass merely dilutes the mortar with inert material.

Fig. 12 shows two groups of tests (lower four curves) which show the effect of substituting trass for part of the cement in concretes otherwise similar. They indicate the greater strength of the plain cement concrete, but the trass-cement concrete curves closely approach those of cement concrete. The uppermost curve indicates the considerably increased strength obtained when trass is added without deducting any part of the cement.

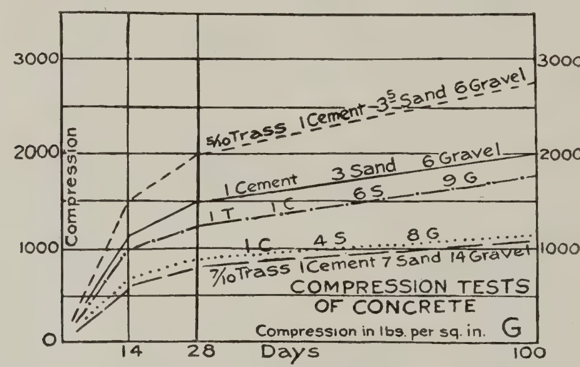


Fig. 12.

CONCLUSION.

Consideration of the facts would indicate that the limited distribution of Trass deposits will always put prohibitive restrictions on its common use in America, but the virtues of Puzzolana would perhaps warrant a series of careful and impartial tests in government or university laboratories with a view to its uses in particular cases which may from time to time arise in marine construction.

GEORGE W. CULLUM.

By

Col. W. R. Livermore,
U. S. Army, ret.

George W. Cullum was born in New York City on the 28th of February, 1809. While quite young he removed with his parents to Meadville, Pa., where he received a very good elementary schooling. In 1829 he was appointed Cadet in the Military Academy at West Point, where he remained until 1833, when he was graduated 3rd in a class of 43—including Barnard, King, Schriver, Shiras, Du Pont, Alvord, and others who took prominent and distinguished parts in the Civil War.

Cullum served as Brevet Second Lieutenant in the Corps of Engineers, July, 1833, to April, 1836; as Second Lieutenant till July, 1838; as Captain till August, 1861; Major till March, 1863; Lieutenant Colonel till March, 1867; Colonel until 1874, when he was retired.

He was engaged; first in the construction of Fort Adams, Newport Harbor, R. I.; Battery Griswold, New London, Conn.; Forts Warren, Independence, and Winthrop, Boston Harbor, Mass.; and on River and Light-house work.

From 1846 to 1850 he was on duty at West Point, devised and constructed Sapper, Miner, and Ponton trains for our armies in the war with Mexico, etc., and published a memoir on "Military Bridges with India Rubber Pontons" as one of a series of professional papers of the Corps of Engineers. He was instructor of Practical Military Engineering there from 1848 to 1851; superintended construction of Cadet Barracks; was Commandant of Sappers and Miners and Pontoniers from 1848-1850; and 1852-1855; on sick leave of absence in Europe, Asia, Africa and West Indies, 1850-1852.

From 1855 to 1860 he superintended work of construction, fortification, etc., along the Atlantic Coast from Massachusettts to South Carolina.

In the Civil War, he served from April to November, 1861, as Aide-de-Camp to Lieut. Gen. Scott, the General in Chief of the Army; then as Chief of Staff of General Halleck, who until July, 1862, commanded the Department of Missouri and of the Mississippi and then became General in Chief of the Army. Cullum remained with him until September, 1864. During this period, he was also Chief Engineer of the Armies commanded by Halleck in Tennessee, Mississippi, Virginia, etc., member of several boards on fortification, etc. He was then Superintendent of the U. S. Military Academy to August, 1866.

As Aide-de-Camp to General Scott he received the rank of Colonel. In November, 1861, he was promoted to Brigadier General of Volunteers. In March, 1865, he was brevetted Brigadier and then Major General, U. S. Army. In September, 1866, he was mustered out of Volunteer Service. He was then stationed in New York as a member of the Board of Engineers on Fortifications and River and Harbor Defence till January, 1874, when he was retired from active service.

Throughout the Civil War Cullum's military career was closely associated with that of General Halleck, and this gave rise to a strong and lasting friendship and widened the field of Cullum's activities, but did not give the same scope for the exercise of his talents that they might have found on the staff of an abler officer. Cullum had thoroughly studied the Art of War as it had been practiced in Europe, especially in all that related to Military engineering in all its branches, and he understood thoroughly how they would have been applied in Napoleonic and Crimæan Wars as well as in former ages. His knowledge and judgment were of great value in planning operations of the Civil War, but did not in every case make due allowance for the changes in warfare due to the improvement in firearms. In 1863 Cullum was still the leading authority on the Ponton Service. He published an excellent account of the System of Military Bridges in use by the U. S. Army, and by the Great European Powers in Europe and Asia. Early in the Civil War, he supervised and edited a translation of Duparcq's "Art of War," and aided Halleck in editing one of Jomini's "Life of Napoleon."

The value of the work of Halleck and Cullum in organization and administration can be better appreciated now, after two years experience in the Great World War, than it was during and immediately after the Civil War.

His experience in early life in building and repairing fortifications was of great value, when, at the end of his career, he was one of the board that revised the system of seacoast defence that was becoming obsolete through the improvements in heavy artillery and the general introduction of steam as the motive power in the navies of the world.

After retirement Cullum lived in New York City, where he took an active interest in the American Geographic Society, of which he was the First Vice-President and an active managing member. He spent his summers in Newport, R. I., where he wrote an "Historical Sketch of the Defenses of Narragansett Bay," with many valuable suggestions about its military importance.

In 1879 he wrote a graphic and critical account of the Campaigns of the War of 1812-15 in a series of brief biographies of the American Engineers who took part, which would be quite interesting to the readers of the PROFESSIONAL MEMOIRS.

Cullum's interest centered about the Military Academy at West Point, where he had been stationed as cadet, instructor, company commander and superintendent. In 1868 he published the first edition of the "Biographical Register," giving a complete record of the stations and duties of every graduate, a list of his writings and a brief account of his Civil History.

In 1870 he was the leading spirit in the organizing of the Association of Graduates, the object of which is to cherish the memories of the Military Academy at West Point and to promote the social intercourse and fraternal fellowship of its graduates. In its annual reports it publishes obituary notices of distinguished graduates, and of these it has been said that Cullum has written more than any twenty-five other graduates.

General Halleck died in 1872, and soon afterwards General Cullum was married to his widow, who died a few years after and left Cullum a considerable fortune. Cullum died in New York City in 1892, bequeathing considerable sums for a Hall for the American Geographic Society, for the continuance of his Biographical Register, for the Association of Graduates, and, above all, for a beautiful Memorial building at West Point, with spacious halls for portrait galleries, and lecture halls, and with sleeping rooms to accommodate returning graduates.

General Cullum was most admired by those who knew him best. His ideas, motives and aspirations were of the highest order—his

intellect was clear, though not perhaps of the most brilliant type. He was an accomplished scholar and this, with his application and energy, won for him a high place in the literary wrold. As Superintendent of the Military Academy, he studied the character and capacity of every cadet and tried to bring out the very best in each.

As founder and benefactor of the Association of the Graduates, he helped to make it practicable for visiting graduates to hold their annual meetings and keep alive the interest and extend the influence of that spirit fostered by the Academy and its surroundings.

FIRE AND EFFECT OF MODERN ARTILLERY.

Prepared by

Capt. C. Beard,
Training Section, Office Chief of Engineers.

To properly design and construct field works of whatever character necessitates a certain knowledge of the methods and matériel that will be used by an enemy in his efforts to destroy them as a preliminary to taking possession of the terrain. That is, the Engineer must be skilled, not only in so organizing a terrain that the defensive and offensive power of troops will be increased, but so that the destruction of his works by an enemy will be made difficult, if not impossible.

The principal means employed by all armies today, for the destruction of fortifications, both "field" and "permanent," is the extensive, and highly scientific use of artillery of all calibres, firing projectiles of many types and methods of employment. The skillful Engineer Officer must possess a general knowledge of the artillery material, its fire possibilities, its fire effect, and the means by which its fire effect can be reduced with respect to the works he is constructing. He must also understand the use of the artillery in the preparation for attack, and in coöperation with the infantry. The following chapter is designed to impart the minimum essentials of the above knowledge, but should be supplemented by independent reading in the field of artillery practice.

BRIEF CLASSIFICATION AND DESCRIPTION OF ARTILLERY MATERIAL.

Classification by Calibre and Weight of Projectile.

(1) *Light*: Including all calibres up to 90 mm.;
(2) *Medium*: Including all calibres from 90 mm. up to 155 mm.;
(3) *Heavy*: Including all calibres from 155 mm. upward.

The smallest calibre in use in land warfare is the light 37 mm. gun which is now considered an infantry weapon. The largest gun used is a development of the present conflict, and is of 520 mm. calibre (about 20 inches). This tremendous bore was unsuccessfully

tried by the Germans, a successful piece being later developed by the French.

The pieces of most frequent employment, and of most interest are those of the first and second classes. The heavy artillery is of course restricted in use owing to its lack of mobility, its high cost—both for the material and ammunition, and its short life. It is used only under special conditions and for important destructions. The light artillery has been developed, by the adoption of motor traction, to an exceedingly high degree of mobility, though it must not be understood that animal traction has been entirely abandoned.

Of the heavier matériels, those up to 210 mm. (8-inch), may be considered as mobile without resort to special roads or tracks upon which to move them. This large calibre material is all truck or tractor drawn when moved over ordinary roads, and for moving on soft ground caterpillar tractors are employed, in connection with "ped rail" equipment on the wheels of the gun carriage itself.

The 210 mm. material, and up, is frequently mounted on special trucks, designed to run sometimes upon the 60 cm. railroads, and for the larger calibres, upon standard gauge roads. A wide diversity in type of mounting, equipment, accessory rolling stock, etc., has been developed, but the employment of all kinds in the same class follows the same general needs.

Classification by Relation of Length and Calibre.

(1) Guns: 25 calibres and upward in length.
(2) Howitzers: 15 to 25 calibres in length and capable of fire at a higher angle in general, than guns.
(3) Mortars under 15 calibres in length and capable of being fired at very high angles of elevation, to produce lines of fall nearly vertical.

The principal tendency with regard to increase in mobility of the artillery is toward complete motorization of all the field material. It is claimed that a great saving in expense, in auxiliary personnel, in forage, stores, and complication is effected, while for service in countries where the road resources are well developed, the scope of action of the artillery is not seriously diminished.

Units—

The units of angular measure used in artillery practice are:

(1) The degree, and its common subdivisions.

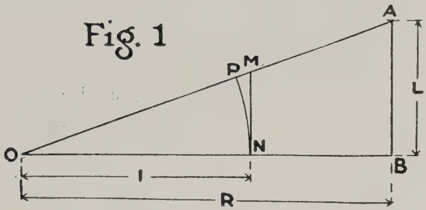


Fig. 1
A
P
M
L
O
N
B
l
R

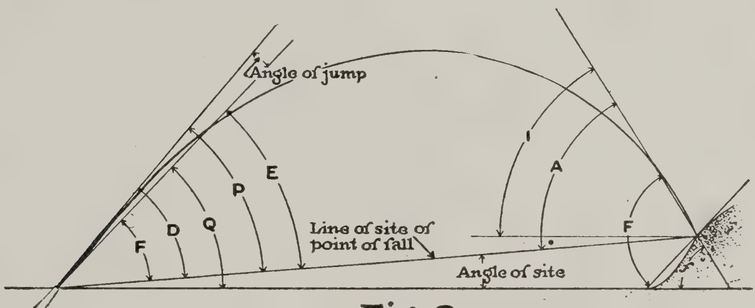

Angle of jump
I
A
E
P
D
Q
F
F
Line of site of point of fall
Angle of site

Fig. 2

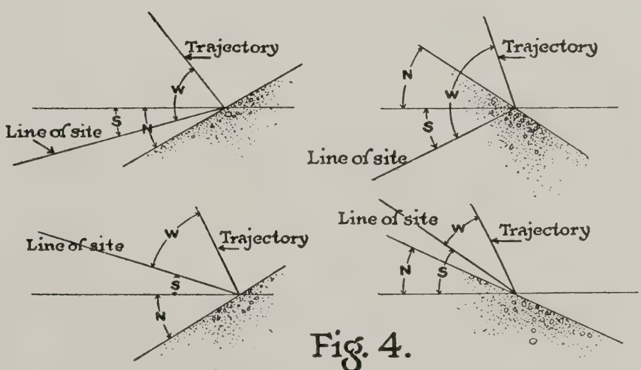

Trajectory
W
S
N
Line of site
Trajectory
N
W
S
Line of site
Line of site
W
Trajectory
S
N
Line of site
W
Trajectory
N
S

Fig. 4.

(2) The grade (French), which is the 400th part of the circumference. Thus $90^\circ = 100$ G. One grade is equal to 10 decigrades.

(3) The mil, which is the 6,400th part of the circumference. (For certain material, the mil has other values.) The mil has a distinct advantage over the other units, owing to its approximately even relation to the numerical value of 2π.

Let AB=L, be a small (relative to the range R) objective, observed from 0. Assume AB perpendicular to 0B, and that the angular parallax of AB at 0 is the angle m (mils). Draw MN parallel to AB at a unit distance from 0 (1), then $\frac{L}{MN} = \frac{R}{I}$

Since m is small the arc PN is very closely equal to MN.

$MN = 2\pi \frac{\text{arc } m,}{\text{circum.}}$ which, subsituted in (1), gives,

(2) $L = 2\pi R \frac{m}{\text{circum.}}$

Now, if m is expressed in degrees

(3) $L = m^\circ R \frac{2\pi}{360} = 0.0175 m^\circ R$

In grades

(4) $L = m^G R \frac{2\pi}{400} = 0.0157 m^G R.$

In mils

(5) $L = m^m R \frac{2\pi}{6400} = 0.001\ m^m R$ (nearly)

In the last expression if L is in meters and R in kilometers we have (6) $L = m^m R$.

That is, 1 meter subtends an angle of 1 mil at a distance of 1 kilometer. The same is true of course for 1 yard at a distance of 1,000 yards.

Definitions Relative to the Trajectory—

The *trajectory* is the path followed by the center of gravity of the projectile during its course in the air.

The *origin* of the trajectory is at the center of the mouth of the piece.

The *line of site* is the straight line adjoining the gun and the target.

The *range* is the distance, gun-point of fall, measured along the line of site to the point of fall.

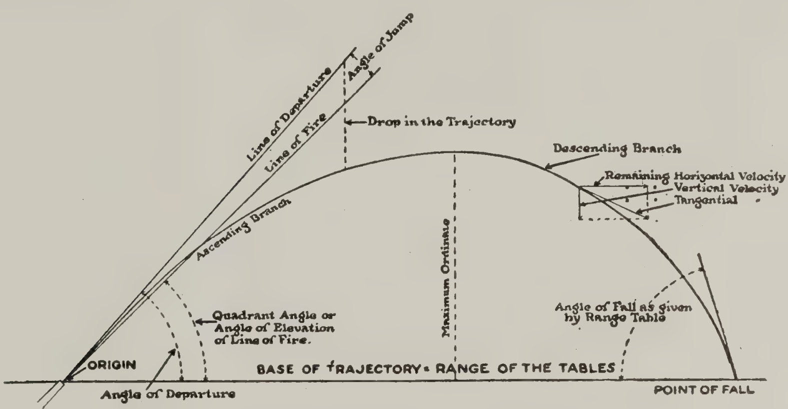
The *distance* of *fire* is the distance, gun target measured along the line of site to the target.

The *angle* of *fall* is the angle formed with the terrain at the point of fall, by the terminal element of the trajectory.

The *line* of *fire* is the indefinite prolongation of the axis of the gun when the gun is laid.

The *line* of *departure* is the indefinite prolongation of the direction of the projectile at the moment it leaves the muzzle of the piece.

The *angle of jump* is the very small angle between the *line* of



Trajectory in Air Projected upon the Plane of Fire

Note This is the trajectory of the range tables

Fig. 3

fire and the *line* of *departure*. (This angle is usually a matter of a few minutes of arc, and is a fixed quantity for a certain gun and ammunition.)

I=Angle of inclination of trajectory at point of fall;
A=Angle of arrival of projectile;
D=Angle of departure of projectile;
E=Angle of elevation above line of site;
P=Angle of projection of projectile;
Q=Quadrant L angle or inclination of line of fire;
F=Angle of fall with respect to the ground;
f=Angle of fall given by range tables.

Range Tables—

In order to facilitate the calculations upon which artillery fire is based, and to make possible the rapid and accurate computation which is very often necessary in the field, Range Tables for the different material have been prepared. These Tables are the result of both experiment at the proving ground, and of ballistic calculations. They show for the various ranges, and types of charge and projectile, the elevation to be given the piece, and certain corrections to be applied thereto.

The elements given in the range tables are based upon a theoretic trajectory, or ideal trajectory, as shown by Fig. 3. This trajectory is based on the following assumptions:

(1) That the piece is new, and true to type.

(2) That the initial velocity of the table is produced by well averaged propellant, at a temperature of 15° C.

(3) That the projectiles have the proper definite weight, and are provided with a fuse of the model determined. It is further assumed by the tables:

(1) That there is no wind blowing.

(2) That the weight of a given volume of the air at the level of the piece, is equal to the standard of the tables.

(3) That the fire is done upon a horizontal plane through the mouth of the piece.

The elements of fire as taken from the range tables are corrected for all deviations of the existing conditions from diagram upon which the tables are based. These corrections fall in three classes.

(a) *Topographic.* (1) The point of fall is not in the horizontal plane through the mouth of the piece.

(b) *Atmospheric.* (1) The weight of the air is not that of the standard of the range tables. (2) The temperature varies also from the above standard. (3) The projectile is influenced by wind, to a degree dependent upon its velocity and direction.

(c) *Ballistic.* (1) The weight of the shell does not conform exactly to the standard. (2) The powder lot is not precisely similar to the type lot upon which the elements of the table are determined. (3) The temperature of the powder is not 15° C. (4) The piece is worn, and therefore not true to type.

For the 75 mm. gun, probably now the most extensively employed field piece in the world, the following ballistic formulæ ex-

Common for each	GERMANY. Max. range.	Max. angle of fall.	Wt. of projectile.	Wt. of explosive charge.
	m.	°	kss.	kss.
Light Field Gı	0,000	30	7.4	1
Light Field H	8,400	45	15.5	2
Heavy Field I	8,600	42	41.5	6
Long Range Gı	1,000	35	41.5	6
Light Trench	450	80	4	13/16
Medium Trencl	1,160	77	46	12
Heavy Trench	970	80	94	47
Mobile Mortar.	9,400	65	118	18.4
Heavy Mobile	2,000	45	......	......
Heavy R. R. H	2,800	65	383	37
Naval Gun, R.	3,000	45	......	......
Heavy R. R. M	4,200	65	804	137

TABLE No. 1.

USUAL TYPES, MODERN ARTILLERY.

Common descriptive name for each class of matériel.		UNITED STATES. Caliber.	Max. range.	Max. angle of fall.	Wt. of projectile.	Wt. of explosive charge.	FRANCE. Caliber.	Max. range.	Max. angle of fall.	Wt. of projectile.	Wt. of explosive charge.	ENGLAND. Caliber.	Max. range.	Max. angle of fall.	Wt. of projectile.	Wt. of explosive charge.	GERMANY. Caliber.	Max. range.	Max. angle of fall.	Wt. of projectile.	Wt. of explosive charge.
			Yds.	°	Lbs.	Lbs.	mm.	m.	°	kss.	kss.	″	Yds.	°	Lbs.	Lbs.	mm.	m.	°	kss.	kss.
Light Field Gun..........	Extremely Mobile Road Mounting.	3″	6,000	15	15	1.6	75	8,500	18	6.125	6.5	3.3	9,500	36	18.5	1.6	77	10,000	30	7.4	1
Light Field Howitzer......		4.7″	10,000	40	60	6	120	8.100	43	18.7	2.6	4.5	7,000	45	35	4.5	105	8,400	45	15.5	2
Heavy Field Howitzer......		155mm	15,800	42	95	14	155	9,500	42	43	10.2	6	10,100	44	100	13	150	8,600	42	41.5	6
Long Range Gun High Power		155mm	17,720	35	95	14	155	15,500	35	42	7.1	6	17,800	42	100	12	150	11,000	35	41.5	6
Light Trench Mortar.......	Non recoil unmounted	3″	746	75	71.6	12.1	58 No. 2	445	80	40	10.5	3	800	75	11	2.1	91	450	80	4	13/16
Medium Trench Mortar.....		6″	1,800	78.5	65	11	150	1,900	75	18	5.3	6	1,420	77	52	11	170	1,160	77	46	12
Heavy Trench Mortar......		240mm	2,300	80	175	79	240	1,025	75	87	46	9.45	2,400	80	152	80	250	970	80	94	47
Mobile Mortar............	Road Mounting.	7″	5,300	70	125	......	220	10,800	65	100.5	25	......	......	......	......	......	2100	9,400	65	118	18.4
Heavy Mobile Howitzer....		240mm	16,500	65	356	44	280	10,950	60	205	63.6	9.2	13,000	45	290	47	280	12,000	45	......	......
Heavy R. R. Howitzer.....	Railroad Mountings.	16″	......	65	1,660	235	400	16,100	65	900	90	12	14,400	45	750	90	305	12,800	65	383	37
Naval Gun, R. R..........		14″	......	15	1,200	154	305	27,000	40	348	30	14	35,400	44	1586	156	380	38,000	45	......	......
Heavy R. R. Mortar.......		12″	12,000	65	1,046	90	370	6,000	65	500	150	......	......	......	......	......	420	14,200	65	804	137

press very closely the values given by the range tables, under the standard conditions. For the purposes of the rough computations made by the Engineer, based upon assumed probable locations of enemy artillery, they will suffice, and all corrections may be neglected.

The relation between range and elevation of the piece is approximately given by

(7) $E=4R\ (R+4)$

in which E=angle of elevation of gun in mils
R=range in kilometers.

The angle of fall with the horizontal is given by

(8) $w=\frac{3}{2}E$ (approximately)

The variation in elevation corresponding to a variation of range by increments of 100 meters from the range R is given by $R\div1$.

The summit of the trajectory is approximately on the bisector of the quadrant elevation.

In the calculation of probable angles of fall with the aid of the above formulæ, which are for a horizontal plane through the mouth of the piece, the following four cases arise, as shown by Fig. 4.

These four cases represent the possible combinations of glacis and reverse slope with a positive and negative angle of site. Now if

w=angle of arrival of the projectile
s=angle of site of the objective
n=slope of the ground

The angle of fall with respect to the ground is given by $W=w-s+n$ when the angles are taken with their proper signs. This will be sufficiently exact, with the small angles of site commonly encountered. The angle of site for any actual or hypothetical battery position with respect to its target can be computed from the topographical map, the range and difference in elevation being known therefrom.

Classification of Projectiles.

Each type of artillery material makes use, according to the nature of the target, object of the fire, and nature of the terrain, of a variety of projectiles. Modern developments of warfare have produced the shell of special employment such as the gas shell, smoke

shell, tracer shell, star shell, etc. Necessities of manufacture have produced the semi-steel shell. Ballistic considerations have changed the form of the base of the shell, and consideration of effect at the point of impact have influenced the fusing. Thus a variety of types is now in existence, a classification and description of the most important following:

I (1) High Explosive Shells.

The types of H. E. Shells in service are:

(A) Steel Shells.

(a) Fused in the ogival end, more than 3 calibres long, thin walled, allowing use of large explosive charge. Consequent light weight decreases range. 20 to 30 per cent of weight of projectiles is in explosive.

(b) Fuse in base of projectile, making possible a massive ogival head capable of profound penetration without fracture due to impact. Capacity for explosive about 6 to 10 per cent of total weight of projectile.

(B) Steel cased, cast iron shells.

(a) Usually fused in the head. Give capacity for H. E. superior to cast iron shell, are less expensive than all steel shells and are ballistically superior. About 20 per cent of total weight is in explosive. Are sometimes, in large calibres, fused in the base to permit the destruction of deep shelters.

(C) Trench mortar bombs.

(a) Usually made of sheet or drawn steel, very light in character, and provided with guide vanes to steady the flight. Countenance for explosive very high, varying from 30 to 50 per cent of total weight.

The most modern development in form of projectiles has been along the line of improving the ballistic qualities by tapering the base of the projectile to give it approximately a stream line form. The disadvantage of this type is that their capacity for H. E. is reduced.

Detonation—

We distinguish

(1) Instantaneous fuses.

(2) Nondelayed action fuses (0 delay).

(3) Delayed action fuses.

(4) Time fuses.

The classes of burst then are

(1) Percussion or impact burst, with instantaneous, non-delayed action, or delayed action fuse.

(2) Time fuse fire, producing burst while shell is still in its trajectory.

By the term "fuse" is meant an assembly of mechanical units, comprising in general an ignition, a communicating, and a detonating element.

The instantaneous fuse is one in which the time of operation is less than 1/100 of a second. Its burst is practically at the instant of impact with the ground. There is also an instantaneous fuse of the supersensitive type, which forms little or no crater on impact with the ground. Both of these types act favorably against personnel and matériel without cover, and against entanglements.

Non-delay action fuses cause the explosion of a shell on impact, to form a crater of moderate depth with but a slight zone of compression downward. It materially localizes the effect of the burst. In very resistant material such as concrete, the burst takes place at or about the limit of the shell's penetration.

Delayed action fuses function in from five to thirty-five hundredths of a second, are made in four durations of delay and are used either to reach matériel protected by overhead cover, or as a fuse against personnel, to cause a burst on richochet.

The time fuse is used with all types of shells, when the burst is desired at some given point upon the trajectory. Most frequently this is the case with H. E. shells or with shrapnel.

II. Shrapnel Shell.

Are of two general types—

A. Made of cast iron, containing a large number of spherical bullets, agglomerated in melted sulphur. The burst of the shell is controlled by a fuse and is due to a small explosive charge in the base of the shell, or in the ogive.

B. Made of a resistant steel shell, designed to give way at the ogive under the explosion of the bursting charge. The group of spherical balls in the body of the shell is propelled from the shell in a fairly narrow sheaf, with a velocity about 100 m. per second, above the remaining tangential velocity of the shell at the moment of burst.

III. Special or Gas Shells are of all the types of body in common use, the shell itself being but a container for the gas producing liquids of whatever kind. In all the projectiles there is a small amount of smoke-producing substance to facilitate the adjustment of fire. The bursting charge is exceedingly light, and produces but a moderate amount of noise in explosion. In the 75-mm. shell the bursting charge is but 25 grammes of Melanite, producing a bursting effect hardly to be considered dangerous from the point of view of fragmentation.

Gas shells are fused with instantaneous or supersensitive fuses to produce a burst at or above the surface of the ground with a consequently more efficient distribution of the toxic liquid they contain.

IV. Projectiles of Special Employment.

The smoke-producing shell is used to mask operations of any kind from the enemy's observation. They are filled with phosphorus compounds and fused accordingly. Star shells are fused with the time fuse, carry a bursting charge which releases one or several small parachutes carrying pyrotechnic illuminants. They are capable of lighting up the terrain for several hundred meters, and last about a minute. The use of the smoke-tracer shell is practically confined to fire against air craft.

Projectiles intended to act against personnel—

I. Projectiles with narrow sheaf.

Principal calibers are the 75 mm., 105 mm., and 120 mm. shrapnel, and the 120 mm. and 155 mm. case-bursting shrapnel. Of the above, the 75 mm. and 155 mm. calibres receive the most extensive employment.

The above projectiles are used with: (a) Time-fuse fire and flat trajectory.

This case is illustrated by Fig. 5. The apex angle is always less than 30° and in the case of the 75 mm. shrapnel is about 19°. The projectile bursting at *E* projects the balls which it contains into the interior of the cone, in which they are uniformly distributed. The maximum effectiveness is obtained for a certain height

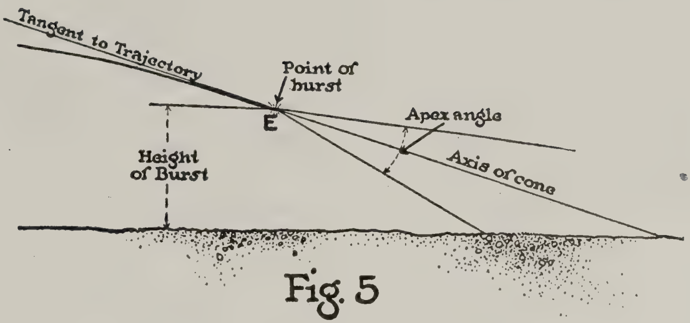


Fig. 5

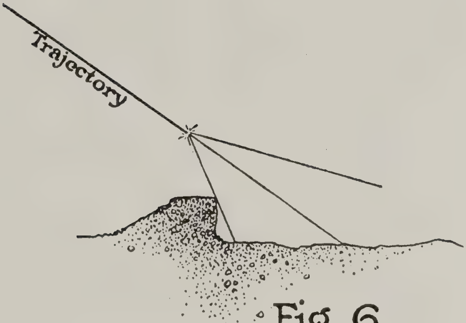


Fig. 6

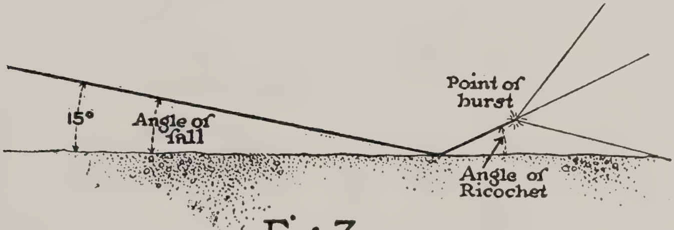


Fig. 7

of burst, called the "type height," which is, for a given range, the height of burst for maximum effect. For the 75 mm. gun it is approximately 3 mils for all ranges.

In the case of personnel sheltered behind an uncovered breastwork as in Fig. 6 it is the practice to use a more curved trajectory, as then the lower element of the cone of balls is more nearly vertical, and the objective is thus better reached. If the personnel behind the breastwork have even the lightest head cover, such as boards covered with 6 inches of earth, the shrapnel balls become entirely ineffective, and this type of fire is not used. Shrapnel are also used with

(*b*) Percussion fire and richochet.

When fired so that the angle of fall with respect to the ground is less than 15°, the projectile richochets, the burst taking place after it starts to rise from the ground. This results in a cone of balls having its axis inclined upward as shown in Fig. 7. The angle of richochet is always greater than the angle of fall. The sheaf sweeps the ground well as long as these angles remain small, which necessitates fire at close range. Above a range of about 1,500 yards for the 75 mm. gun the angle of fall is such that the lower element will pass above the target while the bullets still retain effective velocity. Under general circumstances this type of fire is not used for destructive effect against accessory defenses. Under proper circumstances, it is used for fire in covering barrages.

Method of Action of Time-Fuse Shrapnel.

When the shrapnel bursts in the air at the type height the balls are projected uniformly in the sheaf under the following influences:

(1) Remaining velocity of projectile at point of burst directed along tangent to trajectory.

(2) Additional velocity due to explosion of bursting charge.

(3) Centrifugal force existing at moment of burst due to axial rotation of projectile and tending to spread the sheaf.

The *zone covered* is the total pattern of the sheaf on the ground. The *zone effectively covered* is the portion of the above total pattern reached by balls having 180 m. per second remaining velocity, and in sufficient quantity. That is, the density of balls per square meter of pattern must not be too much reduced by increasing the height of burst. Experience has fixed the most effective height as above. Shrapnel balls, owing to their spherical form, lose velocity

very rapidly, and are considered ineffective when their velocity falls below 180 m. per second.

A study of the patterns shown by Fig. 9 gives rise to the following conclusions:

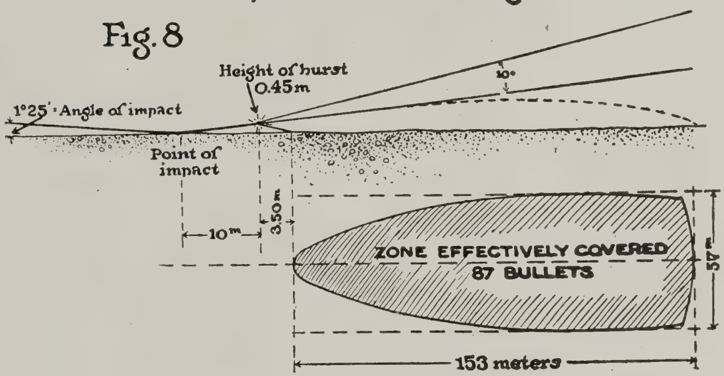
As the range increases:

(1) The depth and width of the total pattern of the sheaf diminish rapidly.

(2) The depth and width of the effective zone diminishes also, but much more slowly, thus the ratio $\frac{\text{effective zone}}{\text{total pattern}}$ increases with the range. It follows that the ratio of effective balls increases with the range.

Pattern on the ground of 75 m/m shrapnel at 1000m range

Fig. 8



It is true, however, that with the increase in range comes increase in angle of fall, which diminishes greatly the effectiveness of the individual ball, whose effective zone is defined as the longitudinal distance in which its trajectory falls within the limits of height of a man standing. This is readily seen from Fig. 10.

The great density of effective balls upon the plane of site should not lead at once to the conclusion that shrapnel is more effective at long ranges than at short. It is the distribution of balls upon a series of vertical planes echeloned in the depth of the pattern and transverse to its axis, which should be considered, as this represents the case of unsheltered personnel, standing or kneeling. In the case of personnel lying down, or sheltered in uncovered trenches, the long range fire would then be most effective.

Consider an element of trench perpendicular to the axis of each pattern. For the fire patterns shown, this trench, if as shown, would then receive a certain number of balls, between its parapet and rear edge, considering only that portion of the sheaf included by the "zone effectively covered." The density of effective balls is not everywhere the same within this zone, nor is the zone of uniform width. It would thus take a fire regulated with the most extreme precision to place the pattern over the trench in such a manner that it would receive the maximum possible number of balls. The most favorable case from this point of view is that of long range fire when the trench of Fig. 11 would receive about 15 balls over a length of 25 meters if the pattern could be properly regulated upon it. The foregoing discussion is intended to show the high degree of protection afforded by an open trench against even perfectly regulated shrapnel fire.

Projectiles With Open Sheaf.

High explosive shells, having delayed action percussion fuse, bursting after richochet, and high explosive shells fired with time fuse, have the characteristics of an open sheaf.

For the 75 mm. shell (initial velocity 550 m. per second) the angle of fall at 4,300 meters or horizontal ground is about 15°, which produces richochet. Thus up to this range, on horizontal ground and at greater or less ranges according to the slope of the terrain, the H. E. shell may be found to ricochet.

It bursts on ricochet at a height above the ground varying from 2 to 10 meters, giving

(1) An ogival sheaf, forward along new trajectory, containing few fragments, and not very effective.

(2) A base sheaf, rearward toward point of richochet, containing a few large fragments.

(3) A lateral sheaf, very open, containing about 1,000 fragments, the central part of which makes upon the ground a trace of about seven-tenths meter in width. The barbed fragments cause very dangerous wounds, because they fly at a great velocity (nearly 1,000 meters). Their radius of effectiveness never exceeds, as a rule, 20 meters, but certain fragments may carry much farther; for this reason it is not advisable to use explosive shells with delayed action when the point of burst is too near friendly troops.

The foregoing type of burst is made clear by Fig. 12.

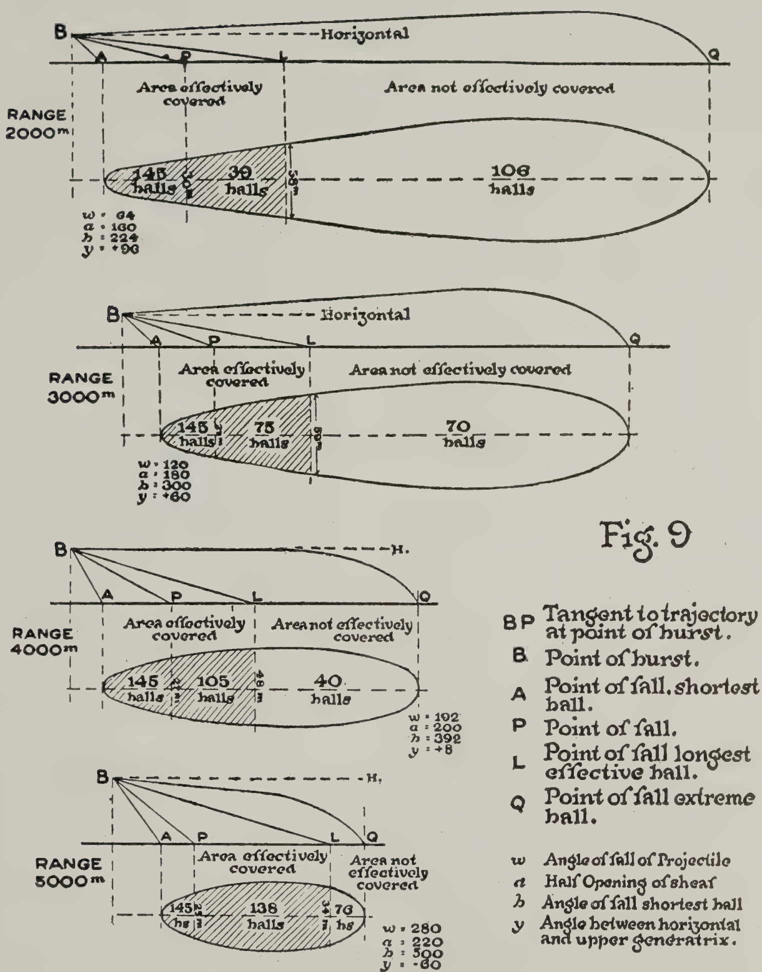

B
Horizontal
A
P
L
Q
Area effectively covered
Area not effectively covered
RANGE 2000m
145 balls
39 balls
106 balls
w = 64
a = 160
b = 224
y = +96
RANGE 3000m
145 balls
75 balls
70 balls
w = 120
a = 180
b = 300
y = +60
H.
RANGE 4000m
145 balls
105 balls
40 balls
w = 192
a = 200
b = 392
y = +8
RANGE 5000m
145 bs
138 balls
76 bs
w = 280
a = 220
b = 500
y = -60
BP Tangent to trajectory at point of burst.
B Point of burst.
A Point of fall, shortest ball.
P Point of fall.
L Point of fall longest effective ball.
Q Point of fall extreme ball.
w Angle of fall of Projectile
a Half Opening of sheaf
b Angle of fall shortest ball
y Angle between horizontal and upper generatrix.

Fig. 9

In case of time fuse fire with the H. E. shell, the burst is illustrated by Fig. 13.

DISPERSION.

When projectiles of the same model are fired from the same piece, under conditions as nearly identical as possible, a number of influences affect their movement, and tend to produce irregularities between successive shots. It must be recognized that the ideal theoretic conditions upon which firing calculations are based are not realizable, and that a variety of causes always tends to produce, in any group of shots, a variation between their points of impact, which is known as their "dispersion." This is bound to be the case, no matter how extreme be the care which is taken to reduce the causes of variation.

The principles causes of these irregularities are:

(1) Differences in weight and balance of projectiles.

(2) Differences in external finish of the projectiles.

(3) Differences in fusing (fuses, from the ballistic viewpoint, must have not only the same weight but the same shape to be identical).

(4) Differences in the weight of powder charge.

(5) Differences in the nature and ballistic properties of the powder.

(6) Difference in the seating of the projectile in the guide cone of the piece and differences in the placing of the powder charge.

(7) Differences in the laying of the gun.

(8) Differences in the nature of the gun carriage and the platform upon which it sets.

(9) Differences in atmospheric condition between successive shots.

(10) Differences due to heating and fouling of the gun.

The above causes of irregularity in the trajectory can be reduced by care to a certain minimum. It is not possible to avoid them entirely, therefore a certain amount of dispersion of points of impact will always exist.

Study of Dispersion.

During the firing of a sufficiently large number of rounds from the same piece, under conditions as nearly identical as possible, it will be observed that the points of fall will group themselves according to a certain law, the nature of which has been determined

by extensive experiments at the proving grounds. This is true of shots falling on a horizontal, an inclined or a vertical surface. The case for a horizontal surface at the same elevation as the mouth of the piece is the one most studied, the relation thereto for inclined and vertical surfaces being known.

When a sufficiently large number of rounds have been fired and the grouping of their points of fall is examined it is seen that they are densest around a certain centrally located point, which is called the "Center of Impact."

Let us consider the case of a fire of 100 shots at the same range under practically identical conditions. If we choose any set of axes, XX and YY, see Fig. 14, and measure the coördinates of each

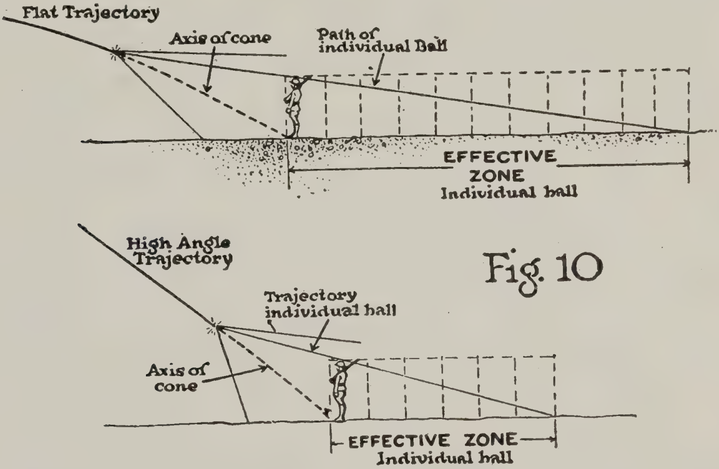


Fig. 10

point of impact with reference to these axes, finally taking their mean, the coördinates thus obtained are those of the mean point of impact or "Center of Impact."

$$\text{Thus} \quad \frac{A1+A2+A3+A4+An}{n}=A$$

$$\text{and} \quad \frac{O1+O2+O3+O4+On}{n}=Q$$

From which we deduce the position of the center of impact with respect to the shots fired, and in relation to the axis chosen.

If then we choose through the center of impact thus located, a set of rectangular axes, one in the direction of the piece, one ⊥ to it, we will observe the following facts:

(1) Dispersion in Range.

(a) Number of rounds falling "Over" the axis XX, Fig. 15, is equal to number of rounds falling "short" of the same axis.

(b) 25 per cent of the "overs" will be in a zone, whose depth parallel to the line of fire is one quarter of the distance to the most extreme shot. The same will be found true for 25 per cent of the "short shots. The depth of this zone which is equal to one-eighth of the total length of the zone of dispersion, is called the "probable error."

(c) In the succeeding three "probable error zones" of both "overs" and "shorts" are found successively 16 per cent, 7 per cent and 2 per cent of the rounds fired.

(2) Dispersion in deflection.

(a) The dispersion in deflection occurs in zones which are parallel to the line of fire. The distribution of rounds falling in these eight zones follows the same laws as those of dispersion in range, but the extent of the zones is much less.

It is seen then, that the total depth and width of the zone of dispersion is eight times the probable error in range or deflection for the particular range and matériel considered. The above laws are general for all types of matériel. It will be readily understood that the absolute value of the probable error differs according to the range and piece employed, but for any given place the probable error as defined above, is an index of its accuracy of fire.

The range tables for any matériel give, for the various tabular ranges, the probable errors both in range and deflection under the assumption that the firing is conducted upon a horizontal plane through the mouth of the piece. These values may be taken without noticeable error for planes above and below the one defined, within the limits usually encountered in practice.

The probable error of the range tables is known as the "theoretic probable error," it being determined under the conditions—as nearly ideal as possible—of proving ground fire. In the field, however, elements enter into the firing which materially affect its accuracy, and the "practical probable error" resulting is found to be about 3/2 of the theoretic.

INFLUENCE UPON THE PROBABLE ERROR OF A TERRAIN NOT HORIZONTAL.

We distinguish two cases.

(1) Probable error as affected by glacis or forward slope.

AM=probable error=E. Let AM=value of probable error corresponding to E, but on a forward slope where gradient is $n°$ and with an angle of inclination of the trajectory at point of fall of $w°$. (This is the angle of fall of the Tables, or it may be calculated by approximate formula already given.)

$$MM = \cos\left([90° - (w+n)] + n\right) AM = AM \cos (90° - w)$$

$$aM = \frac{MM'}{\cos (90° - [w+n])} = \frac{MM'}{\sin (w+n)}$$

$$\therefore aM = AM \frac{\sin w}{\sin (w+n)}$$

Now if we place $\dfrac{\sin w}{\sin (w+n)} = \lambda$

We have a M=AMλ (λ being called the coefficient of forward slope).

(2) Probable error as affected by a reverse slope.

AM=one probable error=E

$MM' = AM \sin w$

$$aM = MM' x \frac{1}{\cos (90° - w + n)} = \frac{MM'}{\cos [90° - (w-n)]} = \frac{MM'}{\sin (w-n)} \therefore aM = AM \frac{\sin w}{\sin (w-n)}$$

Now placing $\dfrac{\sin w}{\sin (w-n)} = \lambda$ we have for average slope $aM = AM\lambda'$

For the above two cases the following two Tables have been prepared, from which the proper coefficients λ and λ' may be taken knowing the slope of the ground and the inclination of the terminal element of the trajectory. By means of these coefficients, the effect of slope upon dispersion may be studied.

TABLE 2.

Dispersion Coefficients.

Forward Slope.

Angle of fall.	Slopes in degrees and percentages.										
	1 Per Cent.	2 Per Cent.	3 Per Cent.	4 Per Cent.	5 Per Cent.	10 Per Cent.	20 Per Cent.	30 Per Cent.	40 Per Cent.	50 Per Cent.	
	35′	1° ¼	1° ¾	2° ¼	2° ¾	5° ¾	11° ½	16° ¾	21° ¾	26° ½	90°
° 5	0.899	0.814	0.745	0.688	0.637	0.469	0.310	0.236	0.193	0.167	0.087
10	.947	.898	.855	.816	.780	.641	.478	.387	.330	.292	.176
15	.965	.931	.900	.871	.844	.732	.584	.493	.432	.390	.268
20	.974	.948	.924	.902	.880	.788	.658	.572	.513	.471	.364
25	.979	.959	.940	.922	.904	.827	.714	.635	.580	.540	.466
30	.983	.967	.951	.936	.921	.857	.757	.687	.636	.600	.577
35	.986	.972	.959	.947	.934	.879	.793	.731	.686	.652	.700
40	.988	.977	.966	.955	.945	.898	.823	.769	.729	.701	.859
45	.990	.981	.971	.962	.954	.914	.850	.803	.769	.745	1.000
50	.992	.984	.976	.968	.961	.927	.873	.834	.806	.788	1.192

TABLE 3.

Dispersion Coefficients.

Reverse Slope.

Angle of fall.	Slopes in degrees and percentages.										
	1 Per Cent 35′	2 Per Cent 1° ¼	3 Per Cent. 1° ¾	4 Per Cent. 2° ¼	5 Per Cent. 2° ¾	10 Per Cent. 5° ¾	20 Per Cent. 11° ½	30 Per Cent. 16° ¾	40 Per Cent 21° ¾	50 Per Cent. 26° ½	
°1											
5	1.128	1.301	1.522	1.839	2.341	....	....	....	....	....	....
10	1.059	1.129	1.205	1.293	1.398	2.325	....	....	....	....	....
15	1.038	1.081	1.126	1.176	1.231	1.604	3.170	....	....	....	....
20	1.028	1.059	1.090	1.124	1.161	1.386	2.265	5.942	....	....	....
25	1.022	1.045	1.069	1.094	1.122	1.280	1.787	2.928	7.571	....	....
30	1.017	1.036	1.055	1.075	1.096	1.216	1.561	2.173	3.506	8.349	....
35	1.014	1.030	1.045	1.061	1.078	1.173	1.428	1.827	2.512	3.911	....
40	1.012	1.025	1.038	1.051	1.065	1.141	1.339	1.625	2.058	2.767	....
45	1.010	1.021	1.031	1.042	1.054	1.117	1.275	1.492	1.765	2.236	....
50	1.008	1.017	1.026	1.035	1.045	1.097	1.226	1.395	1.621	1.926	....

For the case of a vertical wall the table showing effect upon probable error of fire upon a glacis is used, the last column being for surfaces making 90° with the horizontal.

The "angle of fall" is the angle of fall given by the firing tables (angle between horizontal and tang to trajectory at points of fall). The slope n may be obtained as a gradient by taking the VI on the map at the target and dividing by the horizontal interval between contours, multiplying by 100 to reduce to per cent. Or $\frac{\text{VI}}{\text{HI}}$=Tan slope angle.

Dispersion in Time Fuse Fire.

When the projection is used with the time fuse to cause it to burst while still in its trajectory, the deviations of the fuse mechanism from its theoretical operation, superposes upon the deviations before discussed, an additional element causing increased dispersion of the bursts.

If we project upon the plane of fire the position of time fuse bursts observed over a large number of shots we find that the spot diagram so obtained follows the same laws as the dispersion of percussion shots on a horizontal plane.

Let axis XX′ and YY′, Fig. 18, define the plane of fire on which a sufficient series of bursts is projected.

Then the probable error in height for this class of fire is one-eighth of the vertical dimension of the rectangle and in range is one-eighth of the length of the rectangle.

Zone of Security.

In the case of fire executed in the vicinity of friendly troops it is important to establish a zone of security between the nearest elements and the center of impact of the shots. This should be four "practical probable errors" plus the radius of the danger zone due to the explosion of the shells.

In the case of woods near troops, where premature bursts are to be expected, it may be necessary to augment the above zone limits.

For fire on reverse slopes where friendly troops are located these zones of security may become very extended, particularly with a flat trajectory. The above considerations are of utmost importance when the artillery is cooperating with the infantry in the attack, or when a protective barrage is laid down at the request of the infantry.

Dispersion, Slope and the Destruction of Accessory Defenses.

The foregoing study of dispersion has applications of marked importance from the point of view of the location and design of field works. The useful width of entanglements, and the distribution of material in a series of entanglements, is much influenced by dispersion, as is their location with respect to slope. The positioning of trenches with respect to the wire in front of them, the location of trenches with respect to slope and the size of the trench itself, all should be considered, if time permits, with respect to the fire liable to be brought to bear upon them, and the influence of its dispersion.

In a previous chapter certain general limits were set for the proper distance between a trench and its accessory defenses. The upper limit of 125 yards was set by considerations of the closeness with which attacking troops can follow a creeping barrage. The lower limit, of the magnitude of 60 yards, was shown to be somewhat governed by the effective range of bomb and flame throwers, but largely by the interval necessary to prevent the destruction of the trench by the same artillery fire as destroys the wire in front of it. This controlling factor will now be considered.

In the destruction of trenches, and their accessory defenses, protected machine gun emplacements, dugouts and miscellaneous trench structures, the artillery material of most frequent employment is the 75 mm. class.

In the class mentioned will be found the German 77 mm. gun, the French 75 mm. (employed by the French, British and the United States), the U. S. 3-inch field gun, and the British 18-pounder. These guns all have substantially the same characteristics and employment, and for purposes of illustration, the French 75 mm. will be selected as the type of all, with reference when necessary to the French 155 mm. howitzer.

For all matériel in general it may be said that the dispersion increases with the range, and it is therefore the endeavor of the hostile artillery, when selecting battery positions in preparation for a destructive fire, to bring these positions as near to the objectives as possible. As a rule it is possible to place the light field guns and also the 155 mm. howitzers within a distance of from 3,000 to 4,000 meters from the targets. This means that for the destruction of the accessory defenses of a second position, the hostile artillery is put in battery somewhere within the limits of its

first position. The preparation of breaches in the wire entanglements of the first position will usually be accomplished in part by the hostile trench mortars, supplemented by the fire of certain batteries located behind the hostile first position.

Adopting a mean range of 3,500 meters as the distance from gun to objective in a destructive fire regulated upon a trench line or its accessory defenses, we have from the range tables for the 75 mm. and 155 mm. material the following data: Certain elements of fire will also be given at other ranges in order to show the type of variation in dispersion and angle of fall with variation in range. It will be understood also from the table, that powder charges of different weight are provided in order to reach objectives with a varying angle of fall for the same range.. The high angle fire with reduced charge is of course useful against targets well defiladed.

Distance between Trench and Wire.

Assume range of 3,500 meters, using the 75 mm. gun firing the H. E. shell with normal propelling charge and the short instantaneous fuse. The fire of the battery of four guns is regulated so that the center of impact of the shots from each gun coincides with the axis of the entanglement. The planes of fire of each gun of the battery are spaced from 4 to 6 meters apart at the entanglement. With the above elements of fire, we find from the extract of the range table for the 75 mm. material that the dispersion in range is 13.4 meters, in deflection is 1.5 meters, and the angle of fall is 10° 22′. The low angle of fall imposes the use of a non-richochet, or instantaneous fuse. The line of fire is so chosen that it is approximately perpendicular to the wire under destruction.

Superpose upon the 10-meter entanglement the dispersion diagrams for the four guns, using the theoretic values of the dispersion, multiplied by 3/2 to reduce them to the practical values. This is shown by Fig. 19. Thus each probable error zone is about 20 meters in depth.

At the range of 3,500 meters on a horizontal terrain, it will take say 500 shots to open a breach of 25 meters in the entanglement. In the first probable error zone will fall 25 per cent of these shots, or 125, of which—assuming uniform distribution in the zone, the entanglement will receive only ¼ or about 32 shots. Consider the

TABLE No. 4.

Extract From Range Tables for French 75 mm. Gun, Model 1897, Firing French Ammunition. Revised to February 20, 1918.

Kind of Shell and Fusing.	Range at which Fired.	Angle of Fall.	Probable error in Range.	Probable error in Deflection.
	Meters.	Degrees	Meters.	Meters.
Shrapnel with base bursting charge WT 15.90 pounds. Initial velocity f. s. Time fuse.	2000	3°32′	9.0	0.6
	3500	8°37′	13.0	1.3
	8000	37°46′	40.0	5.4
High explosive shell with normal propelling charge. Initial velocity 180 f. s. Using short percussion or instantaneous fuses.	2000	4°2′	10.3	0.6
	3500	10°22′	13.4	1.5
	8000	50°25′	38.6	7.2
Same shell, etc., as above, with first reduced charge.	2000	7°10′	8.5	0.4
	3500	17°10′	12.4	0.9
	6000	45°40′	23.5	1.7
Same shell, etc., as above, with second reduced charge.	2000	9°0′	11.1	0.4
	3500	20°15′	20.0	0.9
	5000	38°50′	37.5	1.7
Semi-steel shell armed with instantaneous fuse.	2000	4°28′	10.3	0.4
	3500	8°28′	12.1	0.8
	8000	26°8′	24.8	3.0
	11000	50°0′	45.0	5.8

TABLE No. 5.

Extract from

Range Tables for 155 mm. Howitzer

Model 1915 Schneider.

Projectiles.

The above gun fires four kinds of projectiles classed in three groups.

1st Group. *Case shot,* mean weight 40.8 kg. containing 416 shrapnel balls with bursting charge of 0.55 kg. black powder.

Shrapnel, mean weight 40.59 kg. containing 270 balls with bursting charge of 0.45 kg. of black powder.

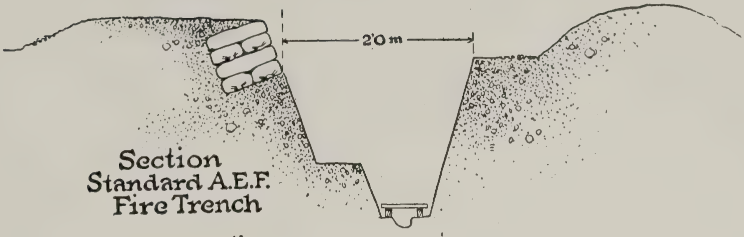
2nd Group. *Long shell* of steel, mean weight 43.0 kg. containing approximately 10.2 kgs. high explosive.

3rd Group. *Explosive shell* of semi-steel, mean weight 43.75 kg. containing approximately 4.5 kg. of high explosive.

The above shells are fired with eight propellant charges according to the range and angle of fall desired. These charges range from 0.88 kg. to 3.54 kg. in weight of special propellant.

Type of Shell.	Charge Used Initial Velocity Meters per second.	Range.	Angle of Fall.	Dispersion in Range.	Dispersion in Deflection.
		Meters.	Degrees.	Meters.	Meters.
Shell of 2nd Group. Long Shell, stream-line base, mean weight 43 kg. Explosive charge, 10.2 kg. H. E. Made entirely of steel.	No. 5 0.880 kg., B. S. P. Initial Vel. 207 m/s	1500	12°25′	6.7	0.6
		2500	24°43′	11.3	1.0
		Extreme 3300	44°50′	21.1	1.8
Short Fuse	No. 2 1.460 kg., B. S. P. Initial Vel. 286 m/s	2000	8°25′	8.1	0.5
		3500	17°22′	12.5	1.0
		Extreme 5900	46°22′	30.3	2.5
	No. 00 3.540 kg.,B. G5 Initial Vel. 440 m/s	8000	36°4′	32.1	2.5
		9000	42°58′	38.5	3.1
		Extreme 10000	51°39′	49.2	3.8
Shell of 3rd Group. Short shell, made of cast iron overlaid with steel, mean weight 43.75 kg. Explosive charge 4.500 kg. H. E.	No. 5 0.880 kg., B. S. P. Initial Vel. 207 m/s	2000	15°9′	11.3	0.7
		3000	26°8′	16.5	1.2
		Extreme 3800	42°0′	20.9	1.8
Short Fuse	No. 2 1.460 kg., B. S. P. Initial Vel. 286 m/s	2000	7°29′	10.2	0.5
		4000	16°54′	17.7	1.1
		Extreme 6900	42°49′	29.9	2.5
	No. 00 3.540 kg., B. G5 Initial Vel. 440 m/s	8000	26°40′	36.2	2.1
		10000	36°50′	44.2	3.0
		Extreme 11900	48°24′	50.4	4.0

NOTE: The 00 (heavy) propellant charge is not used for ranges of less than 8000 meters.



Section
Standard A.E.F.
Fire Trench

Fig. 11

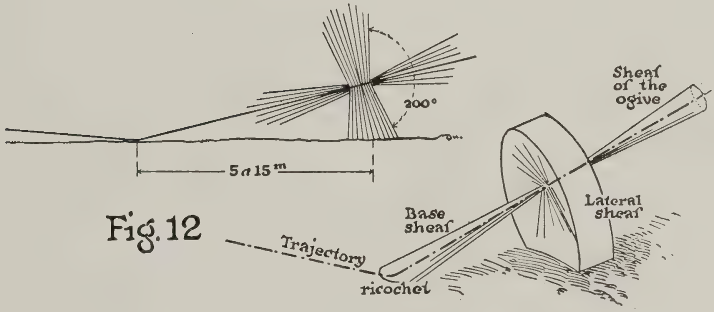


Fig. 12

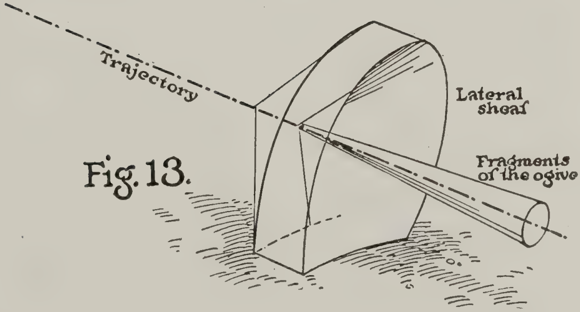


Fig. 13.

location of a Trench 2 meters wide, in each of the zones 2, 3 and 4. This trench will receive in zone No. 2.

$$\frac{2}{20}\times 16\times 500=8 \text{ shots}$$

In zone No. 3

$$\frac{2}{20}\times .07\times 500=3.5 \text{ shots}$$

In zone No. 4

$$\frac{2}{20}\times 0.2\times 500=1 \text{ shot.}$$

It may readily be seen from the foregoing that the trench may, without chance of serious damage, be placed anywhere in the third zone, or in general within 50 to 60 meters of the wire which fronts it.

Fig. 19 shows clearly that it is of no value to increase the depth of single lines of entanglement beyond the amount necessaary to make them difficult of passage by infantry, and difficult of destruction by cutting or by blowing up with elongated explosive charges. Owing to the dispersion of the shots falling in the 50 per cent—or two middle zones, a single entanglement up to about 40 meters in depth would be as easily destroyed as the 10-meter structure depicted. If the center of impact of the fire were regulated upon the axis of the wide entanglement, it would be destroyed by the same number of shots from the battery as the smaller barrier. Thus we see that, beyond a certain upper limit, no advantage against destruction by artillery fire is gained by increasing the wire in depth.

It follows then that to increase the strength of accessory defenses against destruction by artillery—and also to render them more difficult of passage by other means—it is better to dispose the material in successive belts of normal entanglement (from 5 meters to 10 meters in depth), separating these belts by a distance greater than at least two practical probable errors, axis to axis. Then for the economical destruction, it will be necessary to make a new adjustment of fire upon the second line of wire, thus almost doubling the number of shots and the time necessary for the destruction of the single entanglement, even though the material used for the two barriers were concentrated within it.

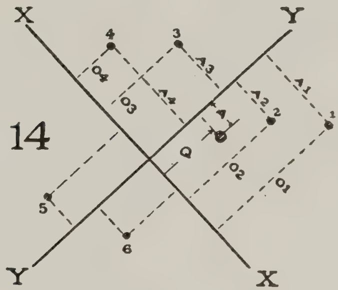


Fig. 14

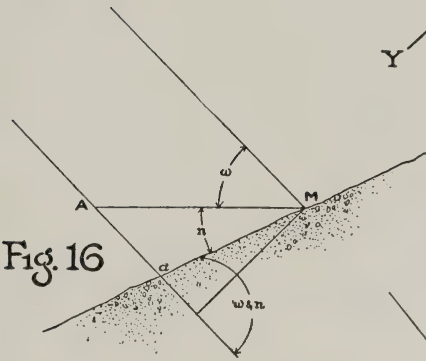


Fig. 16

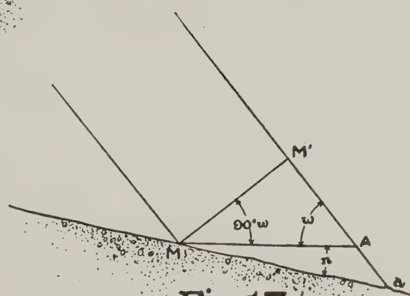


Fig. 17

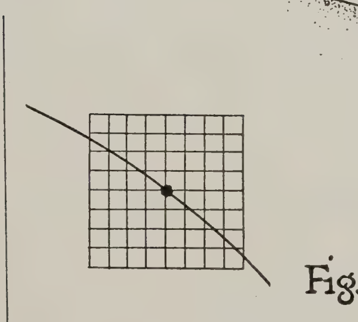


Fig. 18

Effect of Slope on Destructive Fire.

Consider the case of the above trench and entanglement with a fire destruction, regulated upon the wire, and with the organization located

(a) Upon a forward slope;
(b) Upon a reverse slope.

For purposes of comparison and illustration assume that the fall of the ground in each case is 10 meters in 100 meters— that is, that the slope is 10 per cent. This is not uncommon for the slope of the ground in average terrain. Consider first the trench located within the third zone of dispersion upon the forward slope of 10 per cent.

From Table 2 we find that for an angle of fall of 10° 22′ and a forward slope of 10 per cent the slope coefficient=0.641.

Then multiplying the practical probable error by 0.641 we have $0.641\times 20.0=13$ meters as the value of the probable error upon a forward slope of 10 per cent.

The trench then being located at, say, 50 meters from the wire, lies in the fourth zone of dispersion, and therefore out of 500 shots regulated upon the wire, receives

$$0.02\times 500\times \frac{2}{20}=1 \text{ shot.}$$

Now, if the trench itself were the objective of the artillery fire, and the adjustment was good, on a horizontal terrain, out of 100 shots fired by a gun the trench would receive

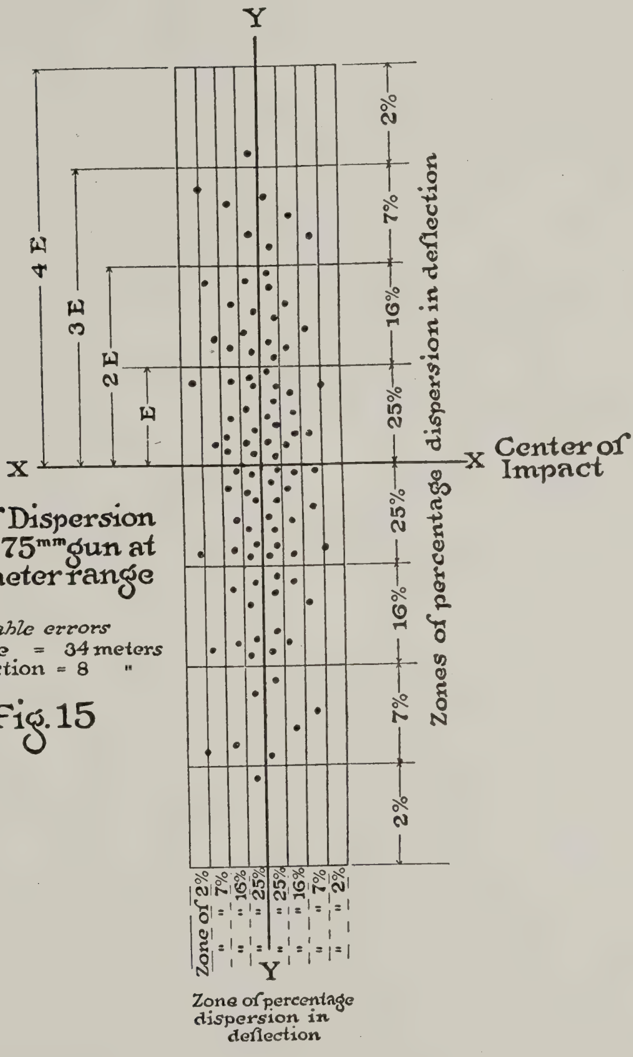
$$\frac{2}{20}\times 0.25\times 100=2.5 \text{ shots.}$$

In the case of the forward slope of 10 per cent the trench would receive at least

$$\frac{3}{13}\times 0.25\times 100=4.0 \text{ shots.}$$

Thus demonstrating the greater ease with which the trench is destroyed upon the forward slope than upon the horizontal terrain.

In the case of the wire located upon the forward slope, the probable error being reduced to 13 meters, the 10-meter belt would receive out of each 100 shots



Zone of Dispersion for the 75mm gun at 7000 meter range

Probable errors
In range = 34 meters
In deflection = 8 "

Fig. 15

$$\frac{10}{26}\times 0.50\times 100=19.2 \text{ shots}$$

while for the horizontal terrain it would receive

$$\frac{10}{40}\times 0.50\times 100=12.5 \text{ shots.}$$

Therefore, if the wire is located upon a forward slope of 10 per cent, it will take—instead of 500 shots to open a 25 meter breach—

$$\frac{12.5}{19.2}\times 500=326 \text{ shots,}$$

thus making the destruction quicker, cheaper and more certain than in the similar case for a horizontal ground.

In the case of the reverse slope, the results of this application of the theory of dispersion are even more striking. The slope coefficient for 10° angle of fall, and 10 per cent reverse slope is 2.325 from Table 3.

The practical probable error then becomes for this slope

$$2.325\times 20=46.5 \text{ meters.}$$

The trench 50 meters from the wire, being now in the second zone, received

$$\frac{2}{46.5}\times 0.25\times 100=1.0 \text{ shots}$$

as compared to 2.5 shots on the horizontal and 4.0 shots on the forward slope.

For the entanglement located upon the reverse slope, out of 100 shots it would receive in the case of well-adjusted fire

$$\frac{10}{93}\times 0.50\times 100=5.4 \text{ shots.}$$

This shows that for the immediate case it will take, not 500 shots to make the required breach, but

$$\frac{12.5}{5.4}\times 500=1160 \text{ shots}$$

The significance of the above discussion can not well be overlooked when considering the relative merits of organization upon a forward or reverse slope, in the case of position warfare. If we take into account the great ease with which a fire for destruction

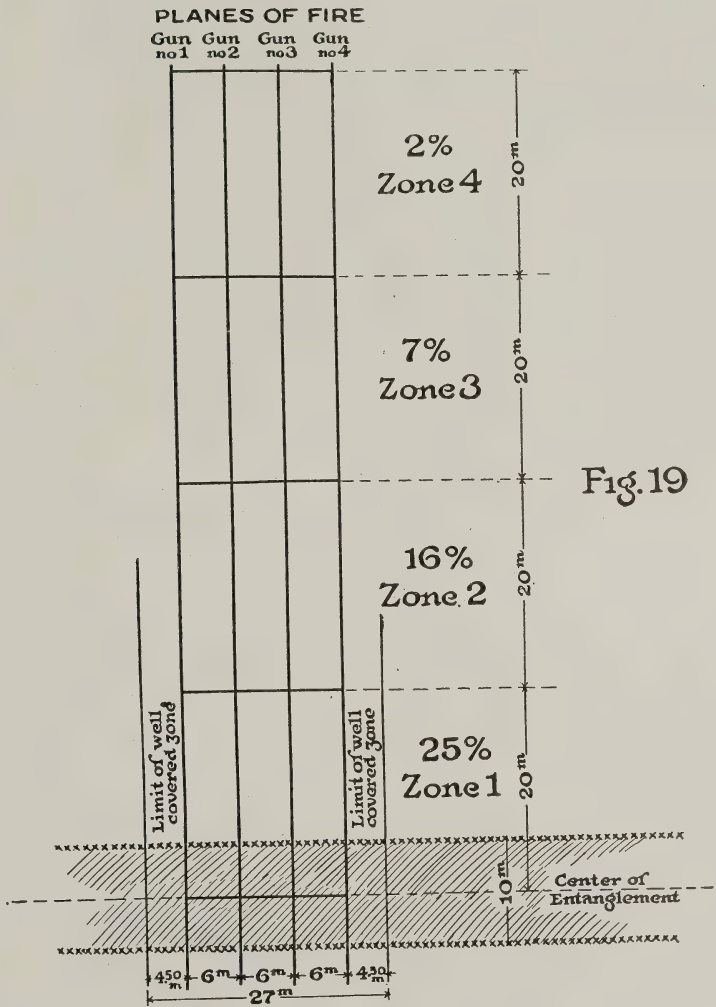

PLANES OF FIRE
Gun no1
Gun no2
Gun no3
Gun no4
2%
Zone 4
20m
7%
Zone 3
20m
16%
Zone 2
20m
25%
Zone 1
20m
Limit of well covered zone
Limit of well covered zone
10m
Center of Entanglement
4.50m
6m
6m
6m
4.50m
27m

Fig. 19

can be regulated upon the forward slope organization, and the difficulty with which it is regulated upon field works sited upon the reverse slope, the above calculations show that the forward slope organization is destroyed with a relative theoretic difficulty of 25 per cent, and the time required for preparation of attack upon it is reduced accordingly. This fact alone affects greatly the degree of surprise with which an attack can be launched after the preparation.

DESTRUCTIVE EFFECTS OF PROJECTILES.

General Considerations.

The destructive effects of modern projectiles are variable according to their mode of employment and their fusing, and much of the efficient employment of the artillery depends upon the proper selection of shell and fuse for a given purpose. A general consideration of what happens upon impact or explosion is of interest. It may be stated that the solid shot without explosive charge is no longer employed in the operations of land warfare.

Projectiles are fused to burst:

(1) While still upon their trajectory (time fuse);
(2) Upon ricochet (delayed-action fuse);
(3) At or near the surface of impact (instantaneous, non-delay or supersensitive fuse);
(4) After penetration, more or less deep, from the surface of impact (delayed-action fuse).

In case (1) their destructive effect is almost entirely limited to personnel and matériel unprotected by field works with over-head cover, and it has already been demonstrated that the shelter afforded by an open trench is in most cases efficient protection against such bursts.

The bursts of case (2) are employed for both shrapnel and high-explosive shell, of 75 mm. calibre most frequently, but occasionally of 155 mm. calibre. Their effects, and the remarks applying thereto, are comparable to those of case (1).

For the destruction of ordinary field works, trenches, light shelters, barbed-wire entanglements, localities, woods, unsheltered personnel and matériel, the burst of case (3) is used, the principal effect being due to the impact and explosion at the surface. The shells of the 75 mm. class can not destroy earth works, and light shelters are only destroyed by them in the case of direct hits. It is

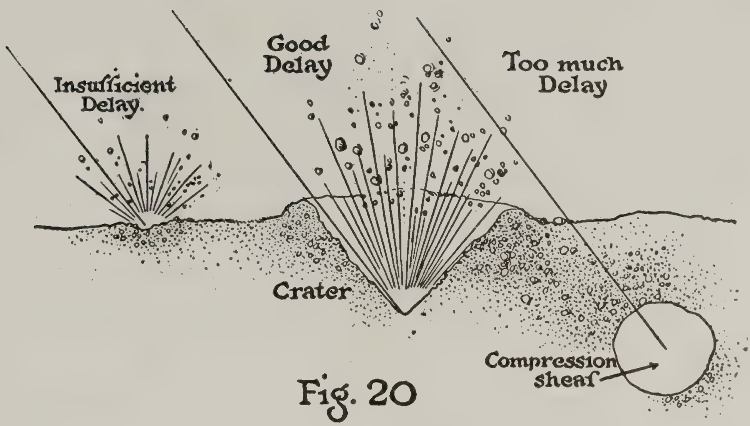

Good Delay
Insufficient Delay.
Too much Delay
Crater
Compression sheaf

Fig. 20

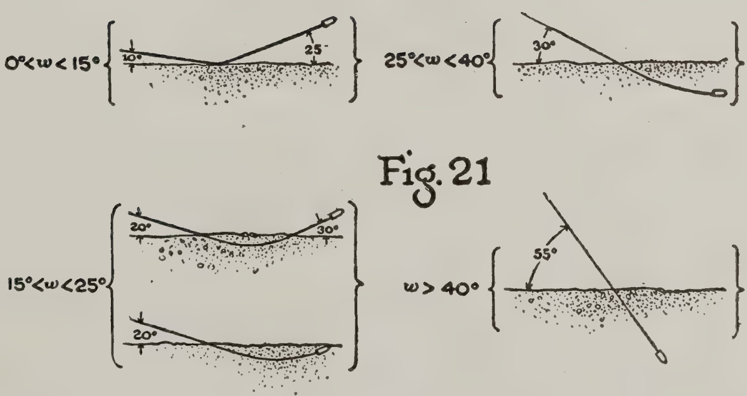

0°<w<15°
10°
25°
25°<w<40°
30°
15°<w<25°
20°
30°
20°
w>40°
55°

Fig. 21

not a shell of employment in the destruction of deep shelters, trenches, emplacements and houses. Experience has shown that the shells of 75 mm. class are sufficient to destroy entanglements, particularly if supplemented somewhat by the trench artillery. In the case of destruction on a counter slope, shells of the 155 mm. class are necessary to supplement the work of the light-field material.

The action of explosive shells bursting upon impact with the instantaneous fuses is, in the case of direct hits upon structures, one of combined shock and explosion. A mass of 16-pound weight (75 mm.) travelling with a terminal velocity of 1,100 feet per second (3,000 m. range) has a striking energy of about 150 foot-tons, which combines with the detonation of its contained explosive to produce the destruction. For bursts in case (3) when the hit is not direct, the result is only dependent upon the blast of the explosion and upon the effect of flying fragments of shell. For the projectiles of small calibre, this effect is not serious against even light shelters, but is of course important against matériel and personnel without shelter.

The fuses producing the type of burst of case 4 are employed mostly for destructions attempted with shells of 155 mm. calibre and upward. This is the type of burst most employed for the destruction of field works and permanent fortifications. The action of the shell is one of combined impact, penetration, and explosion at or near the surface of principal resistance. The shells employed must have a body of great strength, which fact materially reduces their countenance for high explosive, in order not to be shattered upon impact. It is impossible to make even approximate computations of the combined stress effects upon structures, of impact and explosion, but certain observations have been made from experience, and the conclusions drawn are here presented.

The Destruction of Field Works.

The effects to be secured in fire executed against field works are the overthrow of parapets, the obstruction of loopholes, the destruction of light shelters, the throwing down of interior slopes, the displacement of earth so as to fill up or obstruct a part of the trenches, etc.

The shells employed should be capable, to a high degree, of throwing up the earth. This result is obtained by the formation of "craters" at the point of fall of the shell, the earth thrown

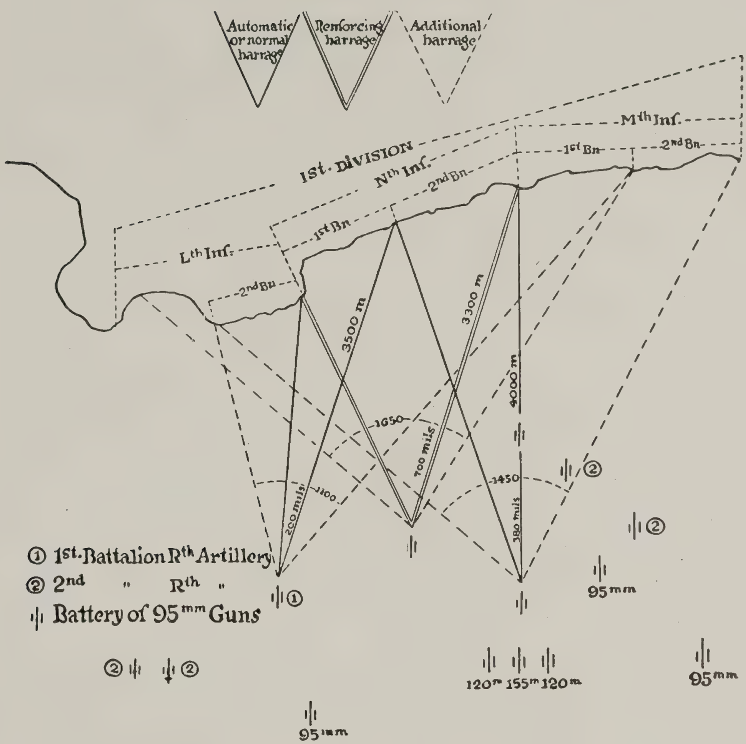


Fig. 22 Barrage Chart. 2 Battalions of Artillery Supporting Regiment of Infantry...

Normal Stable Conditions

0 1 Km 2 Km 3 Km 4 Km 5 Km

out being projected all around the crater. Fire with ricochet does not produce those craters. On the other hand, if the shell bursts without having penetrated the ground, it produces only a slight excavation, sometimes, indeed, entirely insignificant if the calibre is small.

It is therefore advantageous that the shells penetrate to some depth in the ground before bursting, and this result is obtained by using fuses of varying degrees of delay. This depth should not, however, exceed a given maximum, or the effects of the explosion will not be felt on the surface of the ground, Fig. 20. In that case, there is said to be a "camouflet."

The depth giving the maximum crater depends upon the calibre of the shell, its remaining velocity, its angle of fall, and the nature of the ground. It results that, for a given shell and definite fire conditions, there is an advantage in adjusting the duration of the delay according to the resistance of the ground.

Shells of small calibres, containing but little explosive, should not penetrate deeply into the ground; otherwise, a camouflet will be the result. It is therefore evident that shells of small calibres can produce only a superficial upturning of the ground. Only the medium and large calibres, especially if fired with delay, are capable of producing deep craters, thereby rendering field works useless. The effects of the different types of percussion fuse in producing craters is well shown by Fig. 20.

The Destruction of Deep Shelters.

In case of shelters and emplacements provided with overhead and side cover with different degrees of resistance to shell fire, the calibres from 155 mm. upward are employed in fire for destruction. Using the fuse of long delay, the burst is produced after the shell has penetrated the overlying soil, bursting courses, or even a portion of the structure itself, thus causing the maximum of disruptive effect directly against or near the surfaces it is desired to demolish. In the case of concrete emplacements, such as for machine guns, which are partially sunken into the ground, the delay-action fuse acts effectively. When the shell penetrates below the structure, the explosion tends to overturn it, or burst in its floor by upward thrust.

The explosion produced after penetration is particularly effective, owing to the tamping effect of the overlying material pene-

trated, a reaction for the downward or sidewise thrust of the gases being provided. This thrust produces, for example in the case of cave shelters covered with virgin soil, a zone of compression downward and sidewise that tends to collapse the structure, even though penetration to its outer surfaces is not complete and there still remains between it and the point of burst, a considerable layer of undisturbed ground.

For fire executed against deep shelters, high angles of fall are invariably employed to prevent the rise of the projectile to the surface, or too great a deflection from its course. Thus it happens that the guns employed for these destructions are howitzers of medium or large calibre, capable of high angles of elevation. The probable course of a projectile below the surface of the ground, under the influence of its terminal velocity and varying angles of fall, is indicated by Fig. 21.

Destruction of Armor Plate and Concrete Works.

If the armor or concrete can be attacked on a vertical surface, flat trajectory fire is employed. On the contrary, if it is to be attacked on its roof (with surface approaching the horizontal), high angle fire is used.

Generally, an important armored work (gun turret, for example) can be disabled without perforating its armor. A great upturning of the immediate surroundings of the turret is often sufficient to prevent its functioning by destroying its essential mechanisms. This result can be obtained easily enough if the installation of the armored work is rudimentary (turret installed in a first-line trench, for example). But generally the essential parts of such works are protected by a thick glacis of concrete and a hood of armor (cast iron or steel) destroyed with more difficulty.

Attacks on concrete works always require the use of high-explosive shells of largs calibre (calibre 280 mm., and remaining velocity 250 meters).

If the concrete is protected by a layer of material (earth, sand, etc.) it may first be necessary to strip it of the material by a "shaving-down fire" by means of high-explosive shells with fuses with long delay. Then the attack on the concrete work may begin.

Even with large calibres the penetration of the shell into really good concrete is not great. The disintegration of the concrete is only superficial, and if the surface attacked is horizontal, some of the rubbish remains in the excavation and forms sort of a

protecting layer against the following rounds. The deepening of the crater is then rather slow. On the other hand, if a vertical wall of concrete is attacked, the pieces knocked off fall little by little and the breach progresses rapidly.

The most effective shells in attacking concrete works are those of large calibre with very solid ogive, fused at the base, nondelay. The resistance of the ogive is great enough so that it does not break upon impact with the concrete, and it penetrates the outer layer. The shock of its impact produces fissures and a disturbance favorable to the effects of the bursting charge, which explodes immediately after, at the moment when the shell is fairly near the end of its course. The effects produced are considerable.

BARRAGE FIRE AND CO-OPERATION BETWEEN THE INFANTRY AND THE ARTILLERY.

Introductory Remarks.

One of the most important and interesting developments of the present war is the development of the use of the artillery in coöperation with the infantry both in the attack and the defense. The condition of a stabilized front such as has existed in Europe, coupled with more or less fixed emplacements for the artillery material, firing maps of a high degree of precision, and defenses impregnable unless destroyed or neutralized by precise fire from the artillery, has made possible and necessary the developments that will outlined. Treatment of the subject in great detail will not be attempted here, but sufficient discussion and illustration will be given to make clear what constitutes coöperation between the artillery and the infantry, and what are its uses and possibilities.

Definitions—

The following definitions are those of names commonly applied to the various kinds of artillery fire. It can not be said that each definition describes a type of fire, or purpose of fire, that is independent of an unrelated to many of the other types. The uses of each type are variable according to circumstances, and their fields overlap. It is believed, however, that for the purpose of giving a definite elementary knowledge of the subject, the definitions herewith will serve.

Barrage. The concentration of the continued rapid fire of a number of guns or batteries so that the individual centers of impact

of their shots lie properly spaced along a well-defined line. Considering dispersion, it is understood that this line is but the center line of the zone, generally elongated, that is covered by the shots. The foregoing is a broad definition of the term "Barrage."

Standing Barrage. A barrage whose center line remains fixed in position, with regard to the terrain, throughout the duration of fire. Usually applied to a fire on a Trench line, or line of combat groups.

Defensive or Protective Barrage. A barrage laid down upon a predetermined fixed line, between our defensive organizations and the enemy. This barrage is formed by a series of properly located batteries assigned in groups to cover successive portions of the defensive barrage line. For each group, the elements of fire to reach its own section of the line, are recorded in the battery gun-pits so that when not firing otherwise, the guns may be kept laid upon the barrage line, as is customary. The infantry occupying the defensive organizations, in case of need, call for protective barrages along sections of the front, according to a prearranged plan of coöperation with the artillery.

Rolling or Creeping Barrage. A barrage whose center line takes successive positions, in general mutually parallel, and advancing by jumps in the direction of fire by definite linear intervals according to a table of time intervals, the arrangement of which is dependent upon the tactical needs.

Caging or Box Barrage. A fixed or "Standing Barrage" whose center line is approximately perpendicular to the front of attack, and whose function is to isolate the area attacked from support by the defensive or counter-attacking elements on its flanks. It also prevents the withdrawal by the flanks of the occupants of the area.

Back Barrage. A barrage similar in character and purpose to the Caging Barrage, but so placed as to prevent support arriving in the area attacked, from the direction of its rear, and to prevent withdrawal toward the rear.

Fire of Preparation. A fire from all classes of matériel, preceding the hour of launching the attack, and designed to open a way through the accessory defenses of the enemy's position for the advance of the infantry, and also designed to demoralize the enemy personnel and to destroy his field works and defensive dispositions in general.

Fire for Destruction. Usually a fire concentration, regulated

by observation, upon a definite Target with a view to its destruction. It is a phase or element of a Fire of Preparation. (See Fire for Neutralization.)

Fire of Counter-Preparation. A fire of reply to all forms of enemy preparation, increasing in violence as the enemies' fire increases, destroying the assaulting forces before they can launch their attack, and destroying or neutralizing the enemies' batteries. This fire may or may not be regulated by observation.

Fire for Neutralization. A fire at moment of attack, generally conducted with gas shells, against batteries whose map location is known. This fire is not regulated upon the battery by observation and therefore is not intended to destroy it, but reliance is placed upon the wide dispersion of the gas, to prevent the personnel of the battery from serving their guns in a defensive or offensive rôle. (See Counter Battery.)

Fire of Interdiction. A concentration of fire without regulation, upon a zone in which is to be expected the assembly or passage of troops designed to operate in support or counter-attack.

Harassing Fire. A fire, generally intermittent in character, designed to annoy the enemy, deteriorate his morale, prevent his working and carrying parties from operating, and in general to cause him the maximum discomfort and inconvenience. Frequently this type of fire is called for by forward observation posts to be directed with minimum delay, upon designated targets, and without preparatory regulation. (See Fire for Destruction.)

Fire of Retaliation. A fire, generally by observation, concentrated upon an objective, and in retaliation for a similar fire recently conducted by the enemy. The objective generally corresponds in character and tactical importance to the objective just attacked or destroyed by the enemy artillery, and the fire therefore is to the enemy obviously in retaliation.

Counter-Battery Fire. Any fire, not one of neutralization, designed to act against the personnel and matériel of the enemy's batteries. (See Neutralization.)

Artillery in the Offensive.

Under the conditions of position warfare with extensive systems of defensive works organized continuously along the front, and extended in depth perpendicular to the front, no offensive operation can be expected to achieve complete success, unless both the artil-

lery preparation and support are effective. It is essential that the front or sector selected for the attack admit of a full and successful development of artillery fire, and that proper coöperation should be possible with the infantry. For proper preparation of the attack it is essential that the enemy's works be in observation, and for proper support it is essential that the advancing infantry can be followed in their movements, so that the guns firing over them can be controlled rapidly and effectively, thus affording the maximum of support and safety to the attack.

Plan of Attack.

The plan of attack having been outlined by the Commander responsible for its execution, and the matériel available having been indicated, it devolves upon the Commander of the artillery forces engaged to develop in detail and in closest coöperation with the Infantry Commander the plan for the utilization of the artillery.

The plan will lay down the allotment of matériel to the different tasks of the artillery, its grouping, and method of ammunition supply. It will specify the coöperation of airplanes and balloons, will allot command and observation posts, indicate the liaisons with the infantry, and regulate the coöperation and responsibility of the subordinate formations. The lower formations will be charged with the working out in great detail of the elements of fire, ammunition supply, observation and registration, and all factors entering into the execution of their rôle.

The allotment of matériel to tasks is usually about as follows:

Light Field Guns (75 *mm. class*). Cutting wire, destroying light breast-works, interdiction fire, maintenance of breeches, barrage fire of all classes.

Light Field Howitzer (120 *mm. class*). Destroying first-line defenses when within their power, interdiction fire and counter-battery.

Heavy Field Howitzers (155 *mm. class*). Used principally in counter-battery work, and for the bombardment of sensitive points in the enemy defenses. May be used to supplement the work of the 75 mm. material in the destruction of field works, particularly those on reverse slopes.

Long Range Guns of High Power (155 *mm.*). Special destructions at long range, cutting communications, destroying telephone

liaisons, and firing on Brigade and Divisional P. Cs. Also used in counter-battery work.

Very Heavy Howitzers and R. R. Mounted Material. These are used for the bombardment of special points of tactical importance or localities where it is known there are very strong concrete or underground shelters and emplacements, requiring for destruction a heavy shell and high angle of fall.

The Light Trench Mortars. Used to harass the enemy in the final stages of the preparation and may be used to supplement the light field artillery in the preparation of breeches in the wire, and, to a certain extent, in barrage work.

The Medium and Heavy Trench Mortars. Used in the destruction of first-line zone structures, and to harass and demoralize the defenders. They are useful in reducing or neutralizing machine gun nests well to the front, and the heavy trench mortar bomb is capable of important destructions within the limits of its range.

Registration. In order to utilize efficiently the means of observation at the disposal of the artillery, and to avoid indiscriminate and obvious registration, the plan includes a table showing the hours at which each particular grouping of artillery will have the right to undertake its fire for registration, and what observing means are to be had. This registration fire must be reduced in amount to its absolute minimum, and must not reveal its character, as it may give important indications to the enemy.

Duration of the Bombardment. The time necessary to prepare an offensive operation has been subject to wide variations. In some cases, particularly in the first years of the war, preparation has extended for periods of the magnitude of six days. The more modern tendency has been to shorten this period materially, and the latest offensives have been prepared in two or three hours. Thus is the element of surprise to a certain extent fostered and utilized.

Isolation of the Area Attacked. In offensive operations of magnitude, such as those covering the advance along a Corps or an Army front, the projected extent of penetration is usually limited at the flanks, they constituting pivotal points from which the advance pushes forward to its maximum depth at the center. Thus the flanks are not exposed, and the box or caging barrage is not necessary, at least with respect to the entire operation. In the case of small local operations, such as a raid accompanied by ar-

tillery preparation, it is necessary to isolate the area attacked, to permit accomplishment of the raiding mission and subsequent withdrawal of the raiding party. Thus the small operation is frequently comparable in complexity to the large offensive, since to offset the destructive fire here unnecessary there are the complex standing barrage, box barrage, etc , which must be provided to isolate the area attacked.

Support of the Infantry during the Assault. The phase of preparation for an offensive operation having been completed according to the original schedule, or according to a modified schedule resulting from a consideration of its observed effects, the artillery mission becomes one of support to the infantry during its advance, and one of protection to the infantry after it has reached its objectives and is consolidating them either for relatively permanent occupancy or as a temporary holding line preparatory to departure toward a new objective.

Thus, in the phase of movement, the mission of the artillery is to beat down all resistance to the advance from either front or flanks, and in the phase of consolidation, it is to prevent the assembly and approach of counter-attacks of all sizes. It is in the phase of consolidation that the question of direct liaison between the infantry and the artillery becomes one of the utmost importance, as coöperation by a time schedule is then out of the question, and the artillery must be kept closely informed of the situation of the infantry in order to give it the protection essential to its safety and to the success of the attack.

The object of the barrage is to prevent the enemy from manning his defenses, and installing his machine guns in time to arrest the advancing infantry. An intense standing barrage on his trench lines or lines of combat groups will force him to take shelter and also carry his flanking weapons to safety. A rolling barrage preceding the assault waves by a proper interval will neutralize any advance elements of defense not covered by the standing barrage. It also will prevent the enemy from making a defense while at the same time seeking safety from the standing barrage, as he frequently attempts by advancing from his trenches and installing himself with his weapons in convenient shell holes, etc., in front of his lines. With a pair of machine guns so situated, or a few determined automatic rifle teams distributed in shell holes he could, if not neutralized by the rolling barrage, break up a powerful attack over a fairly wide front. It is essential therefore that when

organized terrain, held by determined troops armed with modern automatic weapons, is to be taken with a minimum of losses, a rolling barrage should precede the advance to sweep the ground free from every possible organized or extemporized nest of resistance.

The question of the combined use of the standing and rolling barrages, is one that involves the distance the assaulting infantry has to cover before reaching its first, or its first intermediate objective. It is evident that if the distance between lines, or between point of take off and objective is small (of the magnitude of the depth of the dispersion zone), no rolling barrage is needed. In this case dispersion zone of the standing barrage would cover the area in advance of the objective and render it approximately as untenable as the trench on which its fire was regulated. If, however, the distance to be covered is such that a wide belt of terrain in front of the enemy lines is free of shots from the standing barrage on his trenches, it follows that a rolling barrage will be needed for the reasons above stated.

The back barrage is usually a moving or searching barrage, advancing and withdrawing in depth over a zone behind the area attacked, and designed to sweep the ground to the rear, from which rifle fire or fire from automatic weapons might be directed against the advancing infantry.

Pace of the Rolling Barrage and its Relation to the Infantry. The advance of the rolling barrage is not one of steady progression, but is by jumps at different time intervals. That is, at a stated time the barrage, which has been falling on a given line for a given short period, lifts and comes down on a second line in general parallel to the first and at some definite distance, say 100 meters from it. The advance of the infantry in keeping pace with the barrage then consists of a careful advance until the limit of the zone of security with respect to the barrage is reached, with then a pause until the barrage jumps forward when it can be approached anew. This combination of movements of barrage and infantry results, however, in practically a steady advance for the troops, since the initial spacing between them and the barrage as it first comes down is so arranged that the danger zone is just reached when the first lift occurs, and so on.

The proper rate of advance is of course variable and depends upon the nature of the terrain to be crossed, the distance to be covered to the first objective, the probable conditions of visibility;

and, for the different stages of the advance, the state of exhaustion of the troops. The rate of advance of infantry over broken ground has been found to range from 15 to 75 meters per minute, seldom reaching 100 meters per minute. The British, before the battle of Messines Ridge in May and June of 1917, made use of demonstration barrages along certain fronts both to rehearse the coming offensive and to confuse the enemy. These barrages made jumps of 100 yards every two minutes, thus corresponding to an average rate of infantry advance of 50 yards per minute. During the actual offensive, a study of the successive barrage lines on their operations maps shows that the 100-yard jumps were made in periods varying from two to four or five minutes, and that the barrages were held standing for periods of about ten minutes when each 500 yards approximately of advance had been covered. This was to afford opportunity for the assault columns to form again and take care of casualties, ''mapping-up,'' and necessary consolidation. It also gave to the men a much needed breathing space, and an opportunity to the command to make such possible changes in the supporting fire as the tactical situation demanded.

The degree of closeness with which infantry can or will follow a rolling barrage is a point on which the writers on the subject seem unwilling to commit themselves very definitely. It is of course dependent upon the range at which the fire is conducted, and the type of fuse and shell employed. The precision of fire must be of the highest type, and the coöperation time schedule must be followed rigidly. Under the best circumstances, using H. E. or shrapnel with the fuse of slight delay, so that the bursts are upon ricochet, the infantry can and will approach to within 100 to 75 yards of the barrage. Under less favorable circumstances the interval maintained will be nearer 150 to 200 yards. However, the object of the barrage is entirely defeated, unless the barrage is hugged as closely as possible, and it is considered better to suffer a few casualties from the barrage itself than to have a section or a platoon wiped out by fire from a machine gun, that would not have had time to get into action before being rushed, had the assault wave followed the barrage at a sufficiently small distance.

Artillery in the Defensive.

The defensive barrage has for its object. To stop the enemy attack immediately after it is launched, and in case the attack gets

across and is in contact with friendly troops, to prevent the arrival of reserves and reinforcements. To this end it is necessary that the barrage plan for the defense be worked out in great detail, and that it be possible for the infantry units manning the organized defenses of the terrain, to call for and receive artillery protection properly placed, in a short time.

The length of time in which protection can be received by the infantry is about as follows, computed from the moment the assistance is asked, generally by rocket signal confirmed when possible by telephone.

To obtain automatic barrage—2 minutes after request.

To obtain reinforcing barrage—5 minutes after request.

To obtain help from adjoining artillery groups—10 to 15 minutes after request.

It is generally understood with the infantry that only a certain number of rounds will be fired from each piece, unless word comes to the artillery commander that more protection is needed.

The plan for the protection of a regimental front by normal and reinforcing barrages is shown by Fig. 22. The front primarily protected is that of two battalions of the Nth infantry, and the automatic barrage is laid down by two batteries (8 guns) of the Rth field artillery. This gives a certain density of fire over the regimental front, the density of fire under the conditions shown not being very great. Upon additional call from the Nth infantry, a reinforcing barrage is laid down over the normal automatic barrage and is furnished by an additional battery of the Rth field artillery. With respect to the front of the Nth infantry, these are the sole missions in the defense, of the batteries named. These batteries, however, have extended missions of support on the fronts of adjacent infantry regiments, and their total arcs of fire are as shown.

FUTURE ORGANIZATION.

With plans for the reorganization of the army still in a state of flux, and with various measures being advocated in and out of Congress designed to effect a workable result which shall be to the satisfaction of all concerned, it is of interest to indicate the trend of thought on the organization and duties of the Corps of Engineers. Sufficient time has elapsed since the armistice to permit opinion on this subject to become fairly well crystallized, and while no two expressions can be said to parallel one another throughout, it is possible to separate the ideas in two broad groups. An attempt is made here to present a "composite" or digest of the arguments, pro and con, which have been expressed on some of the salient points of difference of opinion. On other ideas there is substantial agreement, but with many details yet to be settled further discussion is invited.

The expansion of the small pre-war organization of the Corps of Engineers to its imposing proportions on the 11th of November, and the assignment to its field of duty of the multitudinous new activities necessitated by recent advancements in the military art, have caused many members of the Engineer Service to awaken to a realization that the Engineers actually did much that they had not anticipated as being their function—had possibly not thought of as being necessary at all—and that to prepare for the future the great lessons of the immediate past must be heeded and made to bear fruit in a concrete plan, fixing the coming organization and employment of the Engineer Arm.

Any conception of the Engineer service of the future is best formed by a consideration of the activities in which Engineer troops were engaged on the 11th of November. On that date the Corps of Engineers was actually fulfilling the following functions: Front-line operations of all kinds concerned with fortification, lines of communication and other engineering requirements of troops in the face of the enemy; the procurement, storage, distribution, and maintenance of engineer equipment and matériel; the construction and maintenance of all structures in the zone under military con-

trol, except those recognized as being the work of the Signal Corps; the operation of shops and factories, electric light and water systems, together with their installation and maintenance; the conduct of topographical and surveying operations, printing and map reproduction; the construction and operation of light railroads; the design, procurement, development, and both technical and tactical operation of searchlight units; the design, fabrication, and operation of sound and flash ranging devices; the manufacture, development and use of camouflage; and the production of forest products.

The operation of standard gauge railroads, and the Chemical Warfare Service, although started by or under the Engineers, were at the time of the Armistice, under the direction of other independent and co-ordinate agencies.

Thus have been summarized the activities to which the Engineer Service had been committed by reason of its special fitness in point of training, technical specialist resources, and equipment. By virtue of availability the Corps had been charged with the initiation of certain other services which later, owing to expansion and the need of a separate administration, had been made independent. Upon the appropriateness of the activities assigned as functions of the Corps, there is little difference of opinion, with possible exceptions in the cases of the Chemical Warfare Service and the construction and operation of standard gauge railroads.

The Chemical Warfare Service is not related to construction, and is but indirectly related to any other engineering activity, yet it is a service involving technical knowledge of a refined and intricate character. The feeling has been expressed that ultimate authority will not consider this service of sufficient magnitude in peace time to justify a separate organization. But looking back to the experience of the last five years we are led inevitably to the conclusion that to neglect the development of this mode of attack in pace with the usual advancements of the military art in time of peace, would be a sin of omission amounting to folly, especially as we can not prevent its use by a possible foe. On this basis the proper agency for the continuation of the Chemical Warfare Service must be selected, and the opinion widely obtains that the Corps of Engineers, by virtue of special fitness, is best suited to undertake the task.

With regard to the standard-gauge railroads it has been pointed

cut specifically that where adequate systems exist, the operating feature is best undertaken by a separate organization or rather by the continuance of the existing operating force under a proper military supervision. However, when the railroad problem exists also in its construction phase, it is considered that this latter is obviously the work of the Corps of Engineers. When construction and operation must proceed simultaneously under war-time conditions, they are so interwoven that single control is essential.

These conclusions seem to be in agreement with the opinion of members of the Corps of Engineers who have expressed themselves on this subject. It is admitted that the operation of existing railroads within the military area should be conducted by the regular civilian personnel of the system augmented if necessary, and sufficiently militarized to insure the control of operating results in the hands of the military authorities. New construction should be undertaken under the direction of the Corps of Engineers, with the addition to their personnel of qualified civilians commissioned in the appropriate grades. Enlisted personnel should be recruited from the proper trades and employments of railroading. In this manner would be formed an emergency organization, capable of constructing new lines, maintaining and operating existing ones, with the military necessities properly safeguarded, made paramount to the ordinary civil needs, and not subject to the misapprehension, caprice, or neglect of civilian control not fully appreciative of the exigencies of the military situation.

A mutual understanding of requirements and limitations, a community of thought and interest are the only true bases of cooperation. Our organization, or plan for expansion from peace-footing to that of war, must follow natural channels and not attempt to traverse the ridges. Manifestly considering that railroad construction, maintenance and operation is a highly specialized engineering field, it will be necessary to organize and train the peace time nucleus personnel under the direction of that technical service of the army which most closely corresponds to the normal organization of the railway world. These considerations indubitably point to the Corps of Engineers as the logical staff department to organize the service of military railways and fully justify the instructions laid down in our Army Regulations and Field Service Regulations to the effect that the "construction operation and maintenance of these railways is a duty of the Corps of Engi-

neers.'' These contentions are addressed to the special technical phase of railway work, and in no sense oppose the supervision or control of the transportation service by the General Staff. The case is practically analogous to that of the Artillery, the Infantry, or any other arm of the service. The General Staff prescribes their various rôles, specifies when, where and to what extent these arms shall function, and then leaves the technical conduct of their operations to officers and men trained in their execution.

The practical application of the ideas which have taken form as a result of the war's experience, and which are expressed in sum here, would provide for the assignment of qualified officers of the Corps to work for a period of years with the railroads of the country, under some plan providing that their progress through the different phases of railroading would be such as to further their general instruction and acquirement of technique on broad lines, subordinating to this end the usual plan of progress in the line of advancement in one or two departments only. In the same way civilian railroad men, both construction and operating, commissioned in the Engineer Reserve Corps, should receive sufficient military training to afford them an understanding of military exigencies, and to train them in adapting themselves and their professional methods to the requirements of such military situations as might confront them. This calls to mind the statement of the commanding officer of a large and important British railroad unit, a man of broad civilian railroad experience, who stated that he wanted no officer assigned to him, no matter what might be his professional record or degree of technical attainment, until he had served six months in the trenches. This evidently in order that his new subordinates might have acquired a proper appreciation of just why and in what degree the military situation imposes conditions so totally different from those of normal operation. The aim, then, of the military instruction of railroad men, should be an endeavor to teach them, in advance of military operations, what is evident to any engineer who has fulfilled the requirement of the British Colonel.

The administration of these two services, Chemical Warfare and Standard Gauge railroads, it is thought, can be by direct line of control from the Chief of Engineers to the director of the service, and thus, coördinated with the other and older activities of the Corps; the plan of mobilization for war should be perfected

so that only in point of expansion along predetermined lines will a change in organization be necessary when the emergency comes.

With a recent contention that a sapper regiment is the appropriate command of a lieutenant colonel, there seems to be little or no sympathy. It is argued in support of this idea, that the Chief Engineer of the Army Corps will then certainly be a senior to the division engineers and commanding officers of corps and division regiments, and that better and freer intercourse will be possible with staff sections, when the outsider, so to speak, is the junior of the various assistants to the chief of staff. Further, it is contended that owing to the relatively small size of the engineer regiment its command by a colonel is unnecessary.

Response to these arguments has been full and free. The feeling is that, surely, the administration of an engineer regiment, embodying the work of many specialists in different lines, over an area more widespread than is the normal field of operations of the units of any other arm, is a task as complex, and requires executive and technical skill at least equal to that necessary for the command of a regiment of the line. Within certain limits it is not the size of the unit that should govern its appropriate grade of command, but rather the nature, complexity and distribution of its functions. When, in addition to the actual command of the divisional engineer troops, there devolves upon one officer the duties also of division engineer, with the many conferences, reports and reconnoissances necessary, then, indeed, is the day too short under any condition of operation and one main duty or the other will be neglected, or both given necessarily inadequate attention.

The matter of better relations with staff sections can best be handled, it is urged, by giving to the Division Engineer the rank of Colonel and relieving him of the command of troops. His status would be that of an ex-officio staff officer who by reason of time available, social and official contact with the members of the staff and a more exact staff status, would be in a position to accomplish things which many division engineers have found impossible in the past. To say that inferior rank gives better access to staff matters is to argue that superior rank fails to command respect, and that it does not carry with it the forcefulness of character and maturity of judgment necessary sometimes to obtain proper recognition.

An overwhelming percentage of engineer officers who have had

experience as division engineers will, it is thought, argue as above, and among them will be some who will advocate that the command of the sappers of the Division should remain as at present, and that in addition, a colonel of the Corps of Engineers should be assigned as Division Engineer and given definite staff status. Also, it is felt that in the matter of seniority for the Chief Engineer of a Corps it will usually be possible to select for this command a colonel who is in fact senior to the younger and more active men of the same rank who would be selected for the Division. This question, however, gives rise to speculation as to the reason why the command of a Corps organization of engineer troops, involving the coordinations of the operations of from, say, four to seven regiments, totalling some six to ten thousand men, is a more inappropriate command for an officer of general rank than is the command of a brigade of artillery or infantry. If, as seems to be the opinion of the majority, the division engineer should be a colonel, and as has been specifically contended by others, it is necessary that the corps engineer be senior in fact, then it follows that general rank for the corps engineer is the proper solution.

The present composition and disposition of the engineer train has been criticized with unanimity by those who have observed its functioning under the existing organization. It is contended that the train has insufficient enlisted personnel to function properly, either as an integral part of the regiment or as a separate unit. Also, it is not believed that the train should be considered separate from the engineer regiment, since without it the regiment has been found deficient in transportation and tools. The practice of connecting the engineer train with the divisional trains is condemned for the reason that it is thus removed from the control of the organization depending upon its use and most capable of its effective employment. With the division on the march its presence interferes but little, if any, with the mobility of the engineer regiment, while it is at hand, instantly available and under control, if sudden occasion arises for its use. It has been proposed to combine the train with headquarters company, thus eliminating a certain amount of overhead. Whether or not this would be advantageous involving, as it does, the addition of a large special unit to a group of many different specialists, is open to conjecture. The administration of a horsed or motorized train is so different from that of a headquarters company with its many and varied lines of

activity, that it may be preferable to consider the train as a separate entity within the regimental organization, specially officered and recruited to perform the exacting and frequently difficult duties incident to technical transport in field operations.

The band, having come into its own with engineer troops, and the benefits accruing from it—stimulative, recreative, social and otherwise—having been observed, any effort made to reduce its personnel meets with opposition. Likewise it is argued that its organization, being based upon musical consideration rather than on the strength of the unit of which it forms a part, it is improper to reduce the number of pieces, thus rendering it incapable of competing with or showing up as well as the bands of other arms. It has been observed, however, that even when the regimental band was not authorized for engineer troops, most organizations embarking early for overseas took with them a band, which showed a disposition to furnish good music when and where called upon to do so. It may be that the tendency thus exhibited will operate to overcome the deficiencies in the regimental bands of the future, if the proposed diminished organization becomes effective.

With regard to the proportion of engineer troops with the division, it is believed that as at present organized their number is adequate. There are of course, dissenters from this view, but it may be that their ideas have been colored by experiences with operations not to be considered typical or average and that on this is based their belief in the insufficiency of the present ratio of 6⅔ per cent. It is generally recognized that the proportion of engineer troops to total forces, varies with the size of the expedition, the complexity of its operations, character of terrain and development of the theater of operations. The tendency is for the proportion to increase as the size of the total force engaged increases, and also with the degree of organization for war which is met with in the enemy. It is stated that this proportion may reach as high as 20 per cent, all labor and service organizations included.

The proposition that certain specialist units be dispensed with in future operations does not receive universal concurrence. While admitting the versatility of the sapper regiment, demonstrated by their functioning in the A. E. F. from base port to the first wave of an assault upon an enemy position, it is not everywhere conceded that the sapper is capable of efficiently undertaking the work of the water supply regiment, the construction regiment or the

specialist units operating mobile and semi-permanent technical shops. Valuable and diverse as may be the vocational training given the personnel of the sapper regiments, in peace time, it is not true that thereby is produced a complete resource of skilled workers in the trades—technicians of the degree of accomplishment and skill necessitated by the highly complex character of the modern matériel and methods of warfare. To supplement and round out the sappers *per se*, must be added certain units having specialized duties. The point to which this is to be carried is in question, though opinion largely concurs in the statement that the organization of specialist units was somewhat overdone in the late war, in so far as the American Forces were concerned.

With the division operating alone the sappers will ordinarily perform sufficiently well all duties of a technical character. Also in operations involving larger forces, the needs of the division on the march can be adequately met by the division engineer regiment. But in stabilized operations of an extended character, involving advances or withdrawals over a terrain desolated by the viscissitudes of combat, and when the living and sanitary conditions necessary to the health and comfort of a large force must be met and expanded according to the changes of situation, then the specialist unit becomes indispensable in providing the conditions of castrametation, protection, transportation and hospitalization which have developed as essential features of modern combat. Particularly important in this connection—if the lessons of the past are to be heeded in maintaining the right ratio between losses by disease and action casualty—is the service of water supply and it is urged by many that this function can not be properly fulfilled except under limited and special circumstances, by the average sapper regiment.

It is evident, in studying expressed opinions, that the scarcity of common labor was keenly felt during many of our operations. Also the critical observer, could not have failed to be impressed by the very obvious over-recruitment in the lowest enlisted grades, of highly skilled men, whose efforts were manifestly not utilized in a proper manner by their application to necessary but purely manual tasks. It seems to be the opinion that the proper proportion of technical knowledge and technician skill to common labor available, will be maintained in most cases if the officers and non-commissioned officers only, are specialists. While among the privates of an or-

ganization most should be men capable, by previous training and temperament, of doing manual work satisfactorily, it is of course conceivable that certain shop units, for instance, will require an enlisted personnel composed almost entirely of highly skilled mechanics, but in the case of road and railroad troops, water supply, mining and quarrying regiments, it is felt by many that the foregoing proportions will result satisfactorily.

It has been stated that data exists for a decision to be made in the question of the necessary labor troops for permanent assignment to the Corps or Army. The elasticity in amount of requisite labor imposed as a necessary condition by the changing conditions of operations, could be readily supplied by details from line troops in divisional rest areas. This labor resource in the Corps and Army, would reduce the amount of purely manual work—absolutely non-technical—which engineer troops have been obliged to perform, thus releasing their skilled efforts to fields of work paying multiplied dividends in results. The whole subject of labor details is one of some difficulty, due to the inherent idea, possessed by the soldier of the line, and perhaps shared in by his officers and the staffs, that his services as a rifleman or gunner are too valuable to permit his employment with the pick and shovel, yet it is a fact that engineer troops and labor troops combined are not in sufficient number to perform the vast amount of work required at the front, and the other arms must perforce be called upon to supply their quota. It is as much the proper relation of the engineers to the infantry and artillery in construction and organization work, as it is their mutual relation in pure combat, that should be brought out for open discussion and instruction to the staffs. This to the end that staff sections will cooperate with the engineers in furnishing, when necessary, the labor details essential to the prosecution of many programs looking to the preparation of offensives or defensive operations.

In the organization of headquarters detachments of all kinds, it has been the practice, and it has been confirmed by some as a proper general principle, to draw the personnel from engineer troops. The practice is condemned by others as being detrimental to the good functioning of both the organization in the field and the headquarters staff. The proposed adoption of tables of organization for the engineer officer of the Corps and Army is a proper step, but it is not believed that the overhead can be reduced in fact, by

drawing the majority of the required personnel from the troops nearby. There is as much reason for fixing the proper strength of the personnel in the offices of the chief engineer of a corps or an army as exists for a fixed personnel at infantry or artillery brigade headquarters, and certainly sufficient data and experience has accumulated to enable a proper determination to be made of just what constitutes this irreducible personnel.

The foregoing questions seem to be those on which most difference of opinion exists. Some mention has been made of the need in the future for training with light floating bridge matériel, such as was developed in the A. E. F. That this type of bridging equipment, for rapidly crossing small streams with columns of infantry in files, should be neglected in development and instruction after the demonstrations of its usefulness in operations of the A. E. F., is unthinkable. Another and important need of the future which has been mentioned is an adequate provision of properly equipped heavy bridging trains for extended operations in the field, capable of supplying the material and labor necessary for the construction and reconstruction of bridges immediately behind the front of an advancing army. The need of such trains was keenly felt during the last weeks of the war and it is said that operations would have been noticeably hindered by the deficiency, had not the end arrived as it did.

The future will show how well we have learned the lessons of the past months abroad and at home. The task presented to us—of first magnitude in importance—is to arrive at the true conception of the engineer arm in war and in the preparation for war. The deliberations of many boards, the result of many conferences and open discussions, will point the way to the proper future organization of the Corps of Engineers. No constructive work to be undertaken will yield larger rewards than the successful solution of our problems in organization, in appreciation of the mutual duties and responsibilities of the various arms of the service and in the education of staff officers with a view to the proper utilization of all resources in men and matériel.

NATURAL FEATURES OF THE SOUTH ATLANTIC COAST, WITH SPECIAL REFERENCE TO SAVANNAH HARBOR.

By

Col. John Millis,
Corps of Engineers, U. S. Army.

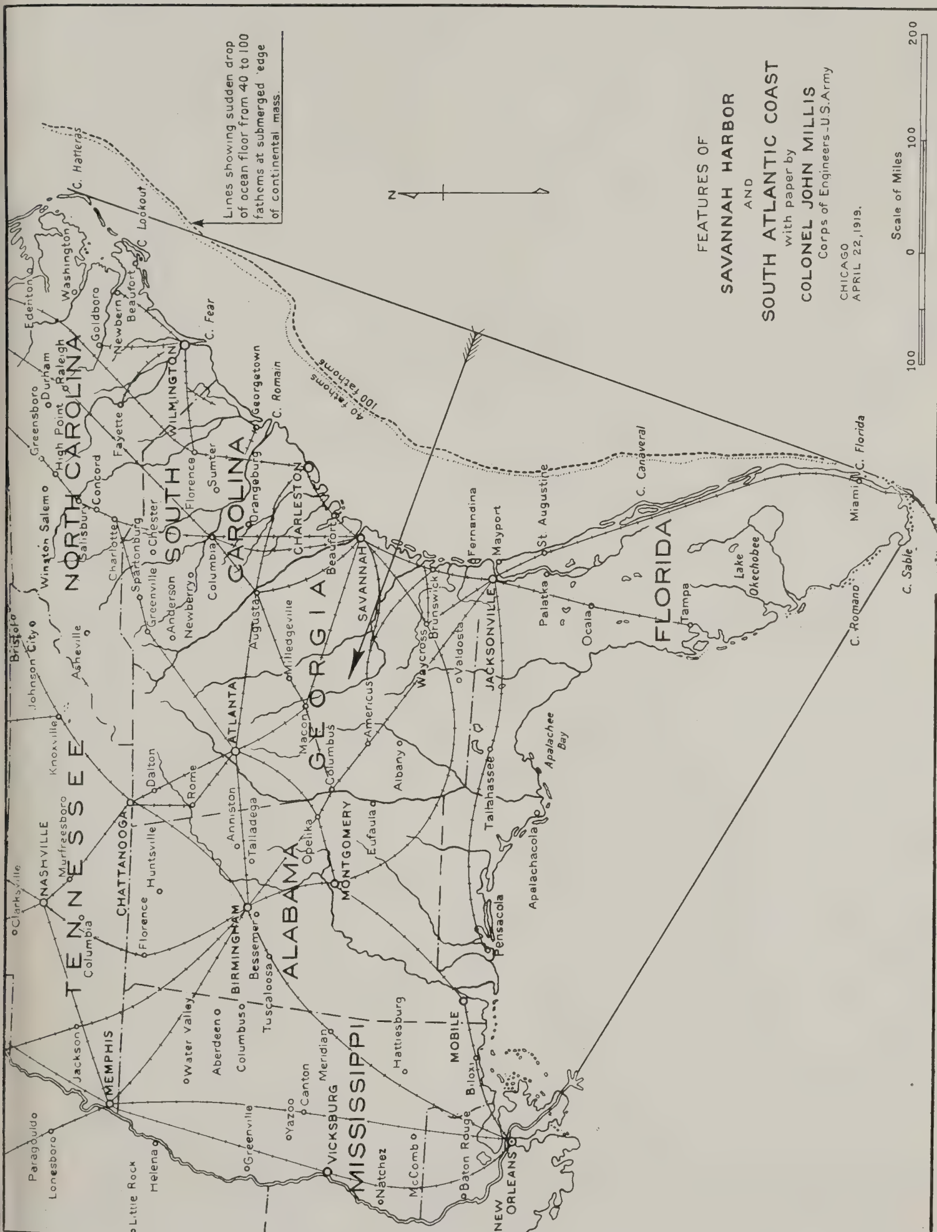
On a general map of the South Atlantic Coast region draw a straight line from Cape Hatteras passing southwesterly and touching the extreme southeast coast line of Florida near Cape Florida, which is not far from Miami. This line will be entirely in the ocean and will represent the "string" of the great bow formed by the included coast line, 825 miles long. The coast of Georgia constitutes 100 miles of this bow in its exact center where the string is 200 miles out at sea, and if we imagine an arrow in position for a shot it will cross the bow at this central portion and have a northwesterly direction, pointing in the general direction of Atlanta, Birmingham, and other cities located in an important inland commercial and industrial region of the south. It will indicate in an approximate fashion the main central axis of the great corn, cotton, timber, turpentine and resin producing section of the Piedmont region, and of the land transportation routes immediately tributary to Brunswick and Savannah, which also afford favorable connections to Charleston and Jacksonville. Along this portion of the coast line are found the harbors at Cape Lookout and Wilmington, North Carolina; Georgetown, Charleston and Port Royal Sound, South Carolina; Savannah, Darien and Brunswick, Georgia; and Fernandina, Jacksonville, St. Augustine, and Miami, Florida, as well as numerous other smaller ports and inlets.

For comparison, note the following figures respecting all of the great "bows" that make up the Atlantic and Gulf Coasts of the United States:

	Direct distance.	Length of coast line.	Depth of bow at center.	
	Miles	*Miles*	*Miles*	
Eastport, Me., to elbow of Cape Cod	275	350	90	Center at Portland, Me.
Elbow of Cape Cod to Cape Hatteras	540	650	120	Center a little north of entrance to Delaware Bay and Philadelphia Harbor.
Cape Hatteras to Cape Florida....	750	825	200	Center about midway between Savannah and Brunswick harbor entrances, Georgia.
Cape Sable to mouth of Mississippi	540	800	230	Center at Apalachee Bay, Florida.
Mouth of Mississippi to mouth of Rio Grande.	530	625	140	Center at Galveston, Texas.

The distances are roughly scaled from the Department of the Interior's Land Office map of the United States, and are only approximate.

Note further the following somewhat remarkable features of the Atlantic Coast line of the United States. From the entrance of New York Bay to the next important entrance northeastward, the eastern end of Block Island Sound, and from New York to the next important entrance to the southwestward, Delaware Bay, the coast in each portion has a generally regular outline, symmetrically convex towards the sea. The extraordinary narrow and deep gorge or cleft in the ocean floor, a continuation of the Hudson River gorge from near Sandy Hook, which extends nearly 150 miles out to sea, forms a somewhat northwardly inclined axis for the New York indentation in the coast line. If there were such a thing as a ship drawing 150 feet of water it would find a well-defined natural channel of ample depth leading to within 10 miles of Sandy Hook Lightship, entrance to New York Bay, but it could not get nearer to Tybee Light, entrance to Savannah River, than a point about 60 miles offshore in a southeast direction. Conditions of shape and symmetry of adjacent coast lines similar to those at the New York entrance are also found by taking Delaware Bay entrance as a


FEATURES OF
SAVANNAH HARBOR
AND
SOUTH ATLANTIC COAST
with paper by
COLONEL JOHN MILLIS
Corps of Engineers-U.S.Army
CHICAGO
APRIL 22, 1919.
Scale of Miles
100 0 100 200
Lines showing sudden drop of ocean floor from 40 to 100 fathoms at submerged edge of continental mass.
40 fathoms
100 fathoms
N
NORTH CAROLINA
SOUTH CAROLINA
GEORGIA
FLORIDA
ALABAMA
MISSISSIPPI
TENNESSEE
C. Hatteras
C. Lookout
C. Fear
C. Romain
C. Canaveral
C. Florida
C. Sable
C. Romano
Key West
Miami
Lake Okechobee
Apalachee Bay
WILMINGTON
CHARLESTON
SAVANNAH
JACKSONVILLE
ATLANTA
BIRMINGHAM
MONTGOMERY
MOBILE
NEW ORLEANS
VICKSBURG
MEMPHIS
NASHVILLE
CHATTANOOGA
Edenton
Washington
Goldboro
Newbern
Beaufort
Raleigh
Durham
Greensboro
High Point
Winston Salem
Fayette
Concord
Salisbury
Charlotte
Spartanburg
Chester
Florence
Sumter
Georgetown
Orangeburg
Columbia
Greenville
Anderson
Newberry
Augusta
Beaufort
Brunswick
Fernandina
Mayport
St Augustine
Palatka
Ocala
Tampa
Waycross
Valdosta
Milledgeville
Macon
Americus
Albany
Columbus
Tallahassee
Apalachacola
Pensacola
Eufaula
Opelika
Anniston
Talladega
Rome
Dalton
Knoxville
Johnson City
Bristol
Asheville
Murfreesboro
Huntsville
Clarksville
Columbia
Florence
Bessemer
Tuscaloosa
Water Valley
Aberdeen
Columbus
Meridian
Hattiesburg
Biloxi
Jackson
Canton
Yazoo
Greenville
Natchez
McComb
Baton Rouge
Paragould
Lonesboro
Little Rock
Helena

center. From the entrance to Chesapeake Bay northward to Delaware Bay and southward to Cape Hatteras a corresponding condition of general symmetry in the coast line appears, even to the tendency to concavity towards the sea which extends in both directions from the Chesapeake Bay entrance about half way to each of the above-named limits, when the coast again becomes convex for the rest of the distance both north and south: And all of the five intervals marked by these main entrances or openings in the coast line extending from the eastern entrance to Nantucket Sound off Cape Cod to Cape Hatteras, between Cape Cod and Cape Hatteras are approximately equal—about 120 to 125 miles each. South of Cape Hatteras we find the three great shallow bays, Cape Hatteras to Cape Lookout, Cape Lookout to Cape Fear, and Cape Fear to Cape Romain, approximately uniform in length, 80 to 100 miles, of about the same width or depth, and each with a remarkably smooth and crescent-shaped shore line. Moreover, at each of these capes there is an area of sandy shoals extending a long distance seaward and pushing the 10-fathom depth curve offshore in the form of a more or less well-defined projection extending from 15 to 30 miles from the point of each cape proper.

An examination of the general ocean chart of the South Atlantic, showing the depths at considerable distances out from the coast line, will bring to light additional features of much importance in connection with commerce and navigation. The ocean in this locality is comparatively shoal and the bottom is very smooth and regular with a very gentle grade or slope towards the southeast for a long distance out to sea, and then along a line which forms roughly a flatter or shallower bow than the coast line the bottom of the ocean abruptly drops from a depth of 40 fathoms to a depth of 100 fathoms (from 240 feet to 600 feet) in going out a farther distance of only a mile or two, or in places even less. This marks the real outer edge or limit of the main continental block or mass, most of which is now elevated above sea level and constitutes North America. The inner limit of the gulf stream follows closely this drop in the bottom of the sea along the coast of South Carolina and Georgia. This feature of the ocean bottom within the area embraced by our gigantic bow and its string has both advantages and disadvantages in connection with commerce. It results in making the entrances to all of the coast harbors, and the approaches to them for a long distance seaward, comparatively shoal in their

natural condition and this has entailed a large amount of artificial work in the way of dredging and jetties, dykes, etc., to improve the depths originally found at these harbors and to maintain such depths. On the other hand, this extensive area of shoal water in the ocean of 100 miles in width at its center causes the great waves of the deep ocean to spend themselves in a large measure before they approach the coast line, and this is of course favorable to all coastwise traffic and to the safety of vessels approaching or leaving these harbors during rough weather at sea. In this respect there is a very marked difference between conditions found on the Atlantic Coast and those on the Pacific Coast of the United States, where deep water comes in very close to shore line and where the outer bars and entrances to the harbors are notoriously dangerous and difficult to pass during storms. It is only proper to add that while the special features referred to in the area under consideration act in a certain degree as a protection against the destructive effects of hurricanes from the West Indies region to which this locality is sometimes exposed, on the other hand the low elevation of the coastal region of the land, which has a direct relation to the shoalness of the ocean waters offshore, results in a somewhat greater liability to damages along shore from the abnormally high tides that occur during West Indies storms than would obtain with greater heights on land even if this should mean greater depths in the neighboring ocean.

Climatic conditions have in some respects an important bearing on the consideration here given to the harbors along this coast. There are, of course, no troubles from ice as in higher latitudes. The rainfall of the southwestern Appalachian Mountain region shows the greatest annual mean of total precipitation in inches of any area in the United States territory next after that adjacent to Puget Sound. This general area comprises the contiguous portions of Virginia, North Carolina, South Carolina, Georgia, Tennessee and Kentucky. A large part of the run-off of this region is over the Piedmont area to the Atlantic, and the remainder reaches the Gulf of Mexico either directly or by way of streams which are part of the Ohio and Mississippi River drainage system. There is a marked difference in the drainage system of the Piedmont area as compared to the great interior basin systems of the Mississippi and the Great Lakes. The two latter are very shallow dish-like depressions in which the whole drainage system is gathered up into

one stem which finds its outlet in a notch in the edge of the depression through the Mississippi and the St. Lawrence Rivers, respectively, while the Piedmont region here considered is an extensive plain which slopes gently and with considerable regularity towards one edge and this constitutes the general shore line of the Atlantic Ocean. The consequence is that the drainage system of this plain consists of a large number of streams of comparatively limited length and drainage basin area, that flow eastward and southeastward along courses approximately parallel and reach the ocean through a number of independent mouths. Much of the country through which these streams flow is covered with surface material which is easily eroded and the water of the streams therefore reaches the ocean bearing much mud and clay in suspension, while large quantities of sand are pushed along on the bottom. This action in connection with the naturally limited depths along shore for a long distance out to sea already referred to, and the influence of the waves, tides, and ocean currents, causes a more or less continuous tendency to shoaling in the entrances to all of the harbors here considered.

The main physiographic features of the land areas along the coast of Georgia and the adjacent shores of South Carolina and Florida, and extending from about Georgetown, South Carolina, to near St. Augustine, Florida, which form the central part of the great bow above referred to, are quite well known, and these present certain unique characteristics which are found nowhere else throughout the whole stretch of our coast line. Approaching from seaward there is, broadly speaking, first a continuous chain of low flat areas broken up into islands by numerous inlets and river mouths that intersect the main coast line. Next inside this general chain of islands comes a comparatively narrow belt of marsh area intersected in all directions by a very complicated system of channels or passages which afford a continuous though shallow sheltered channel for boats throughout the entire portion of the coast referred to. Next inside of this system of passages comes the low lying hard land which slowly and regularly slopes upward towards the interior of the country. While extremely irregular and variable in all the details, it may be stated that the islands generally have their longest dimension parallel to the coast line and the principal ones are from 5 miles to 15 miles long. The general width of the wooded areas of the islands is about 1 to 3 miles and that

of the belt occupied by the marsh area and the passages above described may be stated as varying from 5 miles down to nothing. The general elevation of the islands is nowhere more than an average of a few feet above high tide level—say, 5 to 15 feet. All of these figures are of course only roughly approximate, and they refer to dimensions that have a wide variation. Where not artificially cleared for cultivation the islands are covered with forest trees, mostly live oaks, gum, and a few other hardwood varieties, with occasionally palmettos in the more southerly portions. These islands produce the well-known "long staple" sea-island cotton, which requires a fertile soil and a moist atmosphere. The belt of marsh consists largely of level areas, covered with mud, which have an elevation that is between ordinary high and low tide. They are covered with a uniform rank growth of tall grass but are devoid of trees or shrubs, and evidently no form of vegetation except the marsh grass can thrive on such areas as are submerged by water at every high tide. The main shore adjacent to the marsh areas is marked by forest growth and is distinguished by characteristics and a general appearance very similar to the outer line of islands. The mean rise and fall of tide is in the neighborhood of 5 or 6 feet. The water of the interior channels and passages is muddy and partly fresh, with frequently a red tint in the immediate vicinity of the mouths of the rivers, but elsewhere it is nearly clear and salt.

The above general features appear on all good maps and charts of this locality or will be found in general descriptions of the country, but a closer acquaintance with this seacoast region reveals certain other very interesting peculiarities that have a direct bearing on the questions of harbor and channel improvement and development that do not appear to be generally known. At least only fragmentary and incomplete references to them have been found in any printed literature accessible to the writer. Some of these features were first brought to my attention by Assistant Engineer W. C. Lemen, Savannah District (later Lieutenant Colonel, Engineers, U. S. Army).

While the general appearance of the country and the nature of the sea bottom, as indicated by a casual examination of the coast charts, suggest a land surface that is almost perfectly flat and a dead level, with the exception of a gentle dip to the southeast, it will be found that a curious disturbance must have taken place at

some previous geologic period which has caused some slight but still, when viewed in connection with the subject under consideration, some very important and significant effects. There are many indications that the general surface, originally almost perfectly flat, has been crumpled or puckered into a series of very slight waves or swells and troughs having a general direction of axis which is parallel to the present shore line, and this was no doubt the principal factor in determining the shape and position of this shore line—that is, a line curved to conform to the shape of our gigantic bow—although the visible evidences of these ridges and hollows are mostly limited to the vicinity of the central part of this bow. The evidences of the swells and troughs referred to are, first, the chain of islands above described. While the surface of these islands is in general now above extreme high tide, the material of which they are formed, contrary to a quite general popular belief even among local residents, is not made up of recent sediment brought down by the rivers and thrown up by the action of the winds and waves, but it is of an older geologic period and was formerly at sea bottom level. This is established by the fact that where the islands have been cleared and brought under cultivation large areas are found strewn with oyster shells and the shells of other marine mollusks. While there are a few instances of localities where shells were collected in patches and heaps on the surface by aboriginal man, as in the vicinity of camping or feeding places, this explanation does not account for anything like all of the extensive evidences of this character that are found, and the only tenable theory is that the surface of these islands was originally below low tide and that they have subsequently been raised by some crustal movement of the earth. It should be noted that along the outer or sea boundaries of many of the islands are found more or less extensive belts of wind-formed sand dunes and ridges, but these do not extend any considerable distance inland from the present shore.

In the marsh belt several instances have occurred in connection with dredging and boring operations of finding the remains of trees and stumps, generally of the cypress variety, at levels many feet below the present tide. Since such trees can only grow above low-tide level the areas where they are found must have been at a higher elevation when the trees were growing, and this area must have been depressed presumably in coincidence with the elevation

of the low broken swell or ridge that now constitutes the island chain. Inside of the marsh belt are found evidences in the way of oyster shells similar to those that occur on the isalnds, and in addition there are a few fragmentary evidences of beach sand thrown up into hills or dunes, supposedly by the action of the wind, which is an indication that the main shore line may have been at one time considerably farther inland, at least in places, than at present.

Especially significant is the long low ridge or gentle swell of the surface in the extreme southeasterly corner of the state of Georgia, which has evidently interrupted the former drainage system in that locality and caused the formation of the great Okefenokee Swamp. This swell is about 60 miles long, north and south, and the swamp area to the west of it is about 30 to 40 miles in diameter. The effect of the ridge is peculiarly marked in determining the courses of the Satilla and of the St. Mary's Rivers. The former flows around the north end of the ridge, then directly south and finally turns abruptly eastward and flows to the sea. The St. Mary's River flows around the south end of the ridge, turns directly northward until it approaches within 3 to 4 miles of the Satilla River, at the turn of the latter, abreast of the central point of the ridge, and then makes an abrupt turn eastward to the sea. Another significant evidence of this crumpling of the surface is found in the soundings showing the depths of the sea bottom off the present coast line from a short distance south of Brunswick, Georgia, southward to near St. Augustine. These show a very gentle swell or shoaling in the sea bottom, perhaps 2 or 3 miles offshore, whose general direction is parallel to the present shore line.

It is unnecessary for the present purpose to speculate at length on the causes of this crumpling or fluting, but the general resemblance in form and direction to the vastly greater ridges and valleys of the Appalachian Mountain system, and to the fluting or ridges and hollows in the neighborhood of New Madrid, Missouri, caused by the earthquake of 1812, may be noted. Possibly this very slight fluting along the coast of Georgia and the adjacent states may be looked upon as a very faint echo of the causes that produced the above distant and much more marked disturbances in the earth's crust, and the Charleston earthquake of 1886 will be recalled as a possible indication that the locality is not even yet

in absolutely assured quiescence, although no movement of such a degree as need be taken into consideration in connection with harbor problems has been in evidence since civilized man became interested in this locality.

The area or belt between the Appalachian Mountain system and the Atlantic shore line has been referred to as a generally flat or plane surface, but there are certain rather significant variations from this general rule that should be taken into consideration. Along the west or right bank of the Savannah River between Augusta and the sea will be found an irregular and often broken and interrupted series of bluffs or elevations that give to the right bank characteristics quite markedly different from those that are found on the opposite or South Carolina bank in the vicinity of the river, and similar characteristics less distinct and more fragmentary are found on the right bank of some portions of the streams of the Altamaha River system. At Shell Bluff on the Savannah River is found a very remarkable deposit of fossil oyster shells of gigantic size. These occur at the foot of the bluff near the low-water line, some 80 or 90 feet below the upper surface of the bank. I have learned of reports to the effect that a similar deposit of shells has been found on the South Carolina side at a very considerable depth below the present surface in boring for water or for some other purpose, and these indications suggest a faulting of the crust of the earth in ancient geologic times, or dropping of a considerable area in South Carolina with relative elevation of the adjacent area in Georgia, and a resulting cleft which has determined the course of the Savannah River. The elevated plateau of hard material on which the city of Savannah is located probably is due to some such cause and this may also be the case in a less marked degree at several other cities and towns near the coast—St. Marys, Brunswick, Darien, Bluffton, Beaufort. Only the most meager information as to the present detailed topographic variations of the surface at any considerable distance inland from the coast in this region is, however, available at present. There is little doubt that these features are of a very much older date than those produced by the crustal movements along shore above described. In general direction the Savannah River and other streams of North and South Carolina, are parallel to the submerged gorge extending seaward from New York that has been referred to, but there is slight basis for regarding this fact as significant.

Now, while the actual events and their sequence in connection with the formation of the shore features of Georgia and the adjacent states is largely a matter of conjecture, there is reasonable ground for surmising that the process was something like the following: At some previous period, which in a geologic sense was comparatively recent, since the evidence shows that it was at a time when oysters and other species of shell fish of the present period were in existence and when trees of a variety which seems to have been the same as the existing cypress trees were flourishing, the general shore line in this vicinity was somewhat farther inland than the present outer chain of islands and it may have been of a different shape, but otherwise the conditions were probably very much the same as they are now in respect to climate and rainfall, drainage, general elevation of the land, and depths of the sea bottom. The movement of the crust that produced the ridging or fluting above described then took place, and this was doubtless comparatively sudden, like the changes of surface that occurred in the vicinity of New Madrid on the Mississippi River during the earthquake of 1812. That the shore line was not pushed out by a process that occupied any very great period of time is indicated by the very localized position of the beach sand dunes—those of the present time and the fragments of those of an older date. A very low and gentle swell was pushed up above high tide level along the general line of the present seacoast islands and there was a corresponding depression or trough just inside of and parallel to this elevation. Inland from this another gentle swell was produced in Southeast Georgia, of less extent as to length, which resulted in the disturbance of the drainage system and the formation of the Okefenokee Swamp. This swamp may indeed be also due partially to a general depression, at the same time, of the area which it now occupies. There was also a gentle swell produced offshore, in what is still the sea bottom, along the coast between Brunswick, Georgia, and Jacksonville, Florida. Whether any additional effects farther out at sea were produced the charts do not show. Farther south on the coast of Florida, along the Indian River, are indications of some similar action, but this locality has been observed by the writer only in a very casual way. The ridge or swell corresponding to the chain of coast islands was probably not entirely uniform in elevation and there were, no doubt, low places or interruptions in the continuity of the ridge which, by the action

of the tides and of the water brought down from the land by the rivers, have developed into the numerous inlets that now exist. The rivers continued to bring down sediment which gradually spread through the trough or depression inside the line of coast islands and eventually filled this up in part, though the action of the tides and the currents has preserved the present exceedingly complicated system of bayous and channels. All surfaces elevated above the level of high tide soon became covered with trees and other large growths of vegetation, while the lower areas that were submerged at high water but exposed at low tide were favorable for the growth of the rank marsh grass which now covers these areas. Through the combined influence of the tides and the resultant currents and the deposit of sediment conveyed by the rivers and streams from the land, and especially because of the choking of the channels by large amounts of drift transported from the uplands which the streams traverse, and which in the state of nature were heavily wooded, changes in the locality of the courses followed by the streams in the low flat areas adjacent to the coast were not infrequent. A river or stream after flowing a certain time through one channel to the sea would become obstructed and clogged by drift, and would then break through somewhere else, eroding and developing a new channel in the comparatively soft material which made up the greater part of the land surface. An examination of the detailed coast survey charts will show many inlets and channels extending a short distance inland which approach uniformity in cross-section throughout the length of each and which have considerable width and depth for distances of several miles. They often present the general characteristics of a well-defined river channel with no river or stream of any considerable magnitude now coming in at the upper end. At the outer or seaward end such channels almost always become shoaler, having presumably been filled up by the lateral movement of sand along the coast and with no live river current to keep them open. Otherwise these channels frequently have good navigable depths and a remarkable degree of permanence, with no current influences now acting except those produced by the tides.

Now, as to the practical bearing of these various features on the questions of harbor development and improvement. From a casual examination of the maps and charts and in the absence of familiarity with the various localities from personal visit and

observation it would naturally be concluded that the several bays and inlets along this coast are all very similar in their general characteristics, but a more detailed study shows that there are certain local variations and special characteristics that become quite important in connection with locating cities and manufacturing establishments and making plans for improving the harbors and channels for commercial purposes. Broadly speaking, we may distinguish between the *fresh water* harbors, or those located near the mouths of the larger rivers where the outflow of fresh water predominates over tidal currents bringing in the salt water of the ocean, and *salt water* harbors which are located on inlets that do not now receive any considerable amount of fresh water flow from the land. Savannah[1] is the most typical example of a fresh-water harbor, while Darien, Doboy, and other localities near the mouth of the Altamaha River System also possess similar characteristics. Jacksonville, too, is a harbor in the fresh water class. Charleston, Brunswick, Port Royal Sound (including Beaufort), Fernandina, and Georgetown are the more important harbors that belong to the salt water class. Several of these, including Charleston, Georgetown, Brunswick, and Fernandina, have considerable tributary streams of fresh water which afford navigable depths for several miles above the portions that are salt.

Each of these respective classes of harbors has its drawbacks as well as its advantages. Where fresh water predominates, the teredo and other salt water boring animals can not of course exist, and there is immunity from such attacks for all submerged wooden structures, like the piling of wharves and bulkheads and the hulls of wooden vessels. In the salt water harbors in this latitude the ravages of the teredo are generally very destructive, so that wooden structures require special provision to protect them against these attacks, and wooden vessels, if not metaled or frequently hauled out and treated with protective paint, are liable soon to become injured by the boring animals. There are also questions of available anchorages, suitability of areas near the channel or harbor for foundations and building purposes, and salubrity of the locality, that come in when considering relative advantages of the

---

[1]Savannah Harbor comprises the lower 20 miles of the Savannah River, Tybee Knoll, Tybee Roads, and Tybee Bar, a total distance of 27½ miles, and varies in width from 600 to 1,800 feet. See U. S Coast and Geodetic Survey Chart No 12.

two classes of harbors. The serious drawback for the fresh water harbor is the sediment and sand brought down by the rivers, which produce a constant tendency to shoal, and which limits the depth to which it is practicable to dredge and maintain navigable channels and anchorages. In brief, the problem of securing and maintaining increased navigable depths over those afforded by nature is somewhat simpler and less expensive for the salt water harbor than for the fresh water harbor. In the former the work required is mainly to secure, protect and maintain an entrance channel of proper depth by jetties or training dykes which will increase the scouring effect of tidal currents and prevent the filling of the entrance channel through the outer shoal or the bar, which is invariably found off these harbors, from the lateral drift along the coast and sediment under the influence of ocean waves and currents. These measures are generally supplemented by dredging, or dredging alone may be the means employed. At the fresh water harbors the same influences have to be contended with and in addition the filling effects due to the material brought down by the rivers have also to be combatted.

SAVANNAH HARBOR.

At Savannah the channel, at the city and from the city to deep water at sea, has been improved by training dykes and jetties to widen the harbor, to rectify the channel, and to modify the irregular widths which the river had in a state of nature, so as to increase the scouring effect of the currents. These works are, however, not sufficient of themselves to effect the desired object and have been supplemented by dredging, the dredged material being deposited partly at sea and partly on the marsh areas and in the unused channels abreast of the main river at and below the city. The harbor proper along the river front has been subjected to similar treatment and works have also been undertaken to extend the deep water for a considerable distance above the city. Obviously, the dredging and disposal of dredged material will have to be continued indefinitely under this system, and there is probably some economical limit to the depth which can be secured under these conditions for Savannah Harbor and the approach channel, while the cost of disposal of the dredged material will be a constantly increasing element. There is also a practical limit to the extent to which the channel may be deepened and prolonged upstream, since a point

will eventually be reached where the tendency to fill by the sand and mud brought down by the river will be too great to permit of economical maintenance of the channel by dredging, and the disturbance in the slope of the river and the velocity of the current which will follow from such extension of the deep water channel upstream is also an element to be reckoned with.

Under the conditions as they now exist or as they are likely to develop in the near future, it does not appear that any material change in the present general plan for the improvement and maintenance of Savannah Harbor is warrantable except that it will be appropriate to give careful study to possible economies and an increase in efficiency in the dredging plant and methods of operating. It is, however, appropriate to take a longer look into the future and to speculate on the possible ultimate development and commercial needs at Savannah with the idea of being prepared to consider practically whether a somewhat radical change in the present harbor plans may not sometime be warrantable and possible, and even necessary to enable the city to keep pace with demands of shipping and with developments in other neighboring ports with which there is a degree of competition and rivalry.

The characteristics of the numerous deep inlets along this coast, which appear to be channels formerly occupied by the mouths of the main streams and which are now abandoned by the fresh water entirely, are very significant. As above remarked, many of them show a remarkable uniformity in depth and width for several miles after the inevitable shoal areas at the outer ends are passed in coming from seaward, and they appear to be practically permanent as to depth and width. A conspicuous example of such an inlet is the Wilmington River near Savannah, and this appeared to offer such marked natural advantages for a deep water harbor that its development for that purpose as a supplement to Savannah Harbor, with rearrangement of rail connections, has been quite seriously considered within the last two years. It is not pertinent to the present purpose to refer in detail to the economic considerations which have heretofore rendered this suggestion impracticable. The present geographic information regarding detailed features of the streams and bayous along the coast, except as found in the comparatively narrow belt that has been surveyed by the United States Coast and Geodetic Survey and is shown on their charts, is very meager. Detailed surveys are, however, now in progress under

the cooperation of the Engineer Department and the United States Geological Survey, so that we shall soon have full information regarding the coastal belt in this vicinity and extending back a number of miles inland. These will make possible at least a preliminary study of the suggestion here presented, which is as follows:

Consideration should be given to the possibility of switching the Savannah River out of its present channel entirely at some point above the city of Savannah and diverting it into Port Royal Sound, leaving the present main channel and Savannah Harbor proper as a tidal inlet or estuary having characteristics similar to those of Wilmington River, and not unlike Brunswick Harbor or the inner portions of Charleston Harbor. This may sound quite impracticable and visionary at present, and no doubt this is a proper view of such a plan just now, but the advantages if it should prove to be practicable, will be quite obvious. The fall in the river from Savannah to the sea is now only about 1 foot, and the tidal oscillation at Savannah is practically the same as at the entrance to the channel at Tybee Island, so that the diversion of the river would cause a general lowering of the water surface at Savannah and an increase in the dredging that would be found necessary to secure a given depth by only about 1 foot. While this is something of a disadvantage it will be partly offset by a corresponding greater security at wharves and along the harbor front, generally, against damage from storm tides. The maintenance of the channel would soon be reduced to the dredging necessary to keep the portion of it over the bar at proper depth only, since the depths in the river up to the city would remain essentially permanent once they were secured, and dredging to maintain depths along the city front and in the slips would be practically eliminated. A large anchorage basin in the back river, to be secured by dredging, would then become practicable without any very great subsequent expenditure for maintenance dredging. The present general tendency seems to be towards a constantly increasing cost of maintenance by dredging operations of depth along the harbor front and in the slips. The disadvantages of a salt-water harbor as compared to one in which the water is now fresh and free from teredo would have to be recognized and faced, but even this drawback could be corrected at least in part, without admitting such amount of sand and sediment as would be detrimental, by regu-

lating gates at the dam which must be built in connection with the diversion of the river into a new channel leading to Port Royal Sound. Such gates would permit a regulated partial flow of fresh water into Savannah Harbor and possibly to such an extent as to remedy or at least mitigate the troubles from the teredo without admitting sand, which moves largely on the bottom.

As to the practicability of diverting the river into Port Royal Sound it may be remarked that the general features of this Sound and of the country lying between its head and the present channel of Savannah River, so far as these are known to the writer, indicate very strongly that in former times this was the actual course and outlet for the lower river. Near the head of Port Royal Sound and the course of the present river is a large area, known as the Great Swamp, which, by casual observations from the railroad suggests the possibility of its once having been the course of the main river. This is mere conjecture, but whatever the facts may be, the detailed maps which will result from the surveys above referred to will soon permit a preliminary study of this suggestion. The distance from the point on the present river which might be the point of diversion, to the sea entrance of Port Royal Sound, is about the same as the distance between the same point by the present course of the river to its mouth at Tybee Island, so that the suggested diversion need not affect in any considerable degree the slope and current of the river above. It would, of course, be necessary to provide a lock at the diverting dam, so as to maintain navigable connection between Savannah and the river above to Augusta.

Of course, it must be recognized that an undertaking of this kind would be neither easy nor cheap, and it would raise interstate questions which would have to be worked out beforehand. The first objection to be overcome would probably be questions of possible filling and detriment to navigation in Port Royal Sound, which at present is negligible, and an incidental demand which might be satisfied with general beneficial effect in the negotiations, would be to have established a more direct and easy communication between the city of Savannah and the large area in the adjacent parts of the State of South Carolina that are now practically isolated from communication with an important city. Rice culture on the lowlands adjacent to the Savannah would, of course, become impracticable, but this is now virtually abandoned anyway; on the

other hand, the drainage of these lands could be effected to a large extent, the lands would become available for other general agricultural purposes, and their value would thus be greatly enhanced by the proposed shift in the river channel. The health conditions on these lands and in this vicinity would also be greatly improved.

Note: Since preparing draft of the above, I have learned that a movement for increasing the project depth of Savannah Harbor and ship channel has already been recognized by local interests as necessary to enable the city and port to keep up with the progress of its neighbors and with commercial necessities. Perhaps these notes are rendered the more appropriate and timely by this recognition of the future requirements at Savannah.

THE ROADS OF FRANCE.

By

Col. G. A. Youngberg,
Engineers, U. S. Army.

Our military adventure in Europe is now all but ended. Our expenditures in men, money and material have been tremendous but, with a victory achieved, the investment has not been without return.

In addition to the results of a purely military and political nature, various incidental benefits will accrue which, though intangible and not measurable by any fixed standards of military or commercial success, will be none the less real and valuable.

Hundreds of American young men from widely separated sections of our country, all at an age when the mind is particularly receptive and when new experiences make strong impress, have been thrown into intimate daily contact, under conditions tending to bring out the real character of each individual. They have thus learned to know and appreciate one another and to make due allowances for differing experiences and differing points of view. They have traversed the United States from north to south and from west to east, and their provincialism, inherent to life within restricted limits, has happily vanished into the limbo of the past. They have learned by personal observation that Times Square is not the center of the universe and that California has no monopoly on all the best things of life; they have learned that the east, no less than the west, produces real two-fisted practical men.

Moreover, the experience of some two millions of these young men will not have been circumscribed by our national boundaries, broad as these are, for we have had troops in France and in England, and have maintained contingents in Italy, in Russia, and in Siberia as well. In all of these places our men have been in position to note the differences that obtain between American and foreign practice and to make comparisons which, however much we might like to have it so, have not always been to the advantage of the United States.

In France, of all that has been new or novel to the American soldier, the four or five things that have made the strongest impression are the uniform excellence of the roads; the conservation of forests and the scientific painstaking methods under which these are worked; the careful, intensive cultivation of the land and incidentally the segregation of the farming classes into little villages of most substantial construction, and finally, the complete and excellent road maps covering the entire country.

On account of its intimate relation to the daily lives of all, the highway system is undoubtedly the one item that has made the most preeminent and most universal appeal. When, loaded down with a heavy kit, one has marched for ten, twenty, or even more miles per day and for a week or ten days at a time without a break, there is something about the road under foot that makes even the most unobservant take notice and causes him to think of the roads in the neighborhood of his own home over seas. Or when entire divisions may be loaded on motor vehicles and, thanks to the universal excellence of the roads, may within a few hours time be pushed into action at a critical point a hundred or more miles distant and prevent the loss of a Paris, a Rheims or a Verdun, the experience points a moral with a pronounced appeal.

It is thus more than probable that when our troops shall have returned to the United States and the men shall have resumed their places in the lives of their communities, their thoughts will often revert to the fine roads of France and they will demand that we, too, build up some such system in the United States. In such an event, it may be well to understand something of the organization, conditions and circumstances under which these remarkable roads have been developed, and the principles followed in their construction and maintenance.

As compared with the United States, France is a small compact country which, if transferred in the same latitude to our continent, could more or less completely replace the state of Minnesota, the eastern half of North and South Dakota, and lap over into Canada and Iowa. Its area, exclusive of Corsica, is slightly under 200,000 square miles and is thus approximately the mean of Montana and Texas. Its population of 40,000,000 on a pre-war basis was about 40 per cent of that of the United States, giving it a density of 200 inhabitants per square mile. Except in Brittany, the agriculturists live in villages or hamlets and not on scattered farms as

is the custom in our country. Even in Brittany, small villages are quite numerous and the farms are small holdings intensively cultivated wherever conditions of soil will permit.

The climate does not run to the extremes characteristic of the same latitudes in central North American. The January temperature is about that of wesern North Carolina and northern Georgia or that of Arkansas-Oklahoma for the same month, while the July temperature corresponds closely to that of southern Pennsylvania, Ohio and Wisconsin. The winters are usually cloudy, wet and raw but not cold. The frosts are not severe; snowfalls are light and the snow usually melts within a short time after falling. The summers

Fig. 1. Typical view of national highway in the French Vosges, showing method of planting trees on both sides, piles of road metal for repairs and a small shelter for tools of road patrol.

are not too dry—humidity is fairly high and uniform; rains are not infrequent and seldom, if ever, severe. The total annual rainfall varies from 20 to 40 inches, or in general terms it is equal to that of Iowa and eastern Nebraska. The country as a whole is rolling and excepting certain small districts adequate drainage is not difficult to secure. Road metal, though of the less durable varieties, is also well distributed and does not require long hauls. Further, the very complete canal system lends itself to the cheap transportation of road metal whenever a haul of any distance is necessary. Before the war labor was always cheap, and even now, the wages for common labor in connection with the rehabilitation

of devastated areas are prescribed at 5 francs per day, though an allowance of 5 francs per day is made in certain circumstances to offset the high cost of living. The total compensation is equivalent to something less than $1.90 in U. S. currency.

The government, though republican in form, is rather highly centralized at the national capitol. The 87 departments into which France is divided have not the same degree of autonomy that is enjoyed by our states. The administration of each department is in charge of a Prefect who is appointed by the President of the Republic on the recommendation of the Minister of the Interior. The departments in turn are successively divided into ''arrondisse-

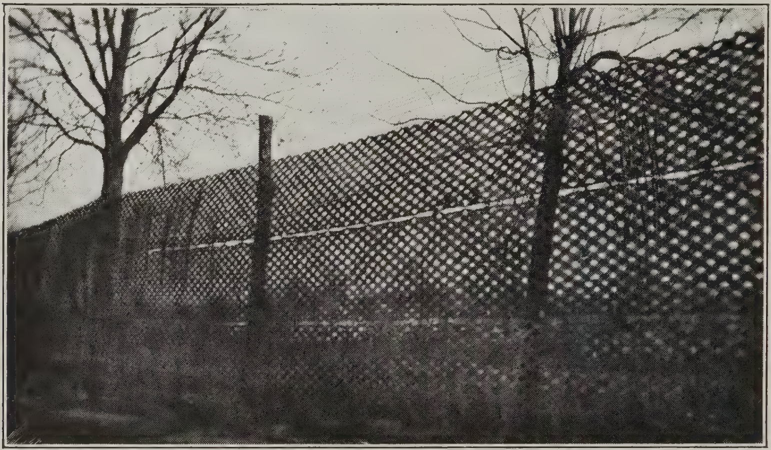


Fig. 2. German Road Camouflage consisting of strips of jute woven through chicken wire netting. Many miles of this screening were hung along exposed stretches of road to mask the movement of trucks and troops which might otherwise give the enemy a clue as to comtemplated operations. The Allies made use of similar screening but jute was usually woven in at right angles. Straw matting, brushwood panels and other materials were also used.

ments,'' ''cantons,'' and ''communes,'' and the system of government thus echelons the authority and responsibility through the various officials directly from the capitol to the smallest municipal unit.

The construction of high grade roads dates back to the Roman occupation and was more or less intermittently the subject of concern to various monarchs from that epoch till the time of Napoleon Bonaparte. To that gentleman, as a corollary to his dictum that an

army moves on its belly, good roads became of the greatest importance and under him the French road organization was finally put on a permanent and stable basis. The roads of France were thus highly developed before the railroads or the canal, and hence their construction did not bring them into competition with the demand for these more modern transportation facilities. With possibly one or two exceptions, all of the circumstances above indicated conduce to the development of good roads. So intimately are they part and parcel of the life of the rural Frenchman, that their deterioration causes him acute anxiety far beyond the damage measured in intrinsic terms of labor or money.

ORGANIZATION OF FRENCH HIGHWAY SERVICE.

The administration of the highway service in France is national in its scope and devolves upon the Department of Public Works; more specificially it comes under the jurisdiction of the well known "Corps des Ponts et Chaussées," or Division of Bridges and Roads. For the national highway service this corps is represented in each governmental department by an engineer-in-chief who supervises the work throughout his department. He has under him an assistant engineer for each arrondissement, who in turn supervises *conducteurs,* or inspectors, each in charge of a sub-division comprising from 30 to 60 miles of road.

The Department Highway Service, as distinguished from the National Highway Service, is administered in each department by an *agent-voyer* or road surveyor-inspector who has under him representatives for each arrondissement, canton or other minor governmental unit. Finally, the system includes road-tenders or patrols called *cantonniers* who do the actual work required in the maintenance of the highways. Each such patrol is in charge of a fixed section of road, the length of which varies according to the density of traffic and the method prescribed for maintenance. It may be as much as 4 miles in open country and only 1 or 2 miles in the neighborhood of large cities or in villages. These cantonniers, who are often provided with assistants, are formed into groups or *brigades* of 5 or 6 men with a chief cantonnier in charge. There are 11,000 cantonniers maintained at national expense and about 85,000 more maintained at the expense of subordinate municipal units. Many of these work on part time or at stated seasons only.

The highways are divided into two major classifications called "routes" and "chemins" which in our terminology might be "trunk highways" and "regional roads." The "routes" are further classified as National and Departmental. The former belong exclusively to the National Government and are constructed and maintained by national appropriations. They conform in general to the grand natural currents of travel along lines originally determined by the topographic configuration of the country itself. They radiate from Paris as a center and connect the larger cities and principal points of military importance by the most direct lines consistent with other major considerations, such as easy gradients, good drainage and low maintenance costs. The departmental

Fig. 3. French Road Camouflage consisting of panels of brushwood and straw matting erected on frames at right angles to road at suitable intervals to mask it from view of enemy in right background. This view shows material being taken down by French women for use as fuel, it being no longer needed for its original purpose.

routes belong to the departments and connect important points in the same department or in adjoining departments. They are maintained at department expense, either by the Corps des Ponts et Chaussées or by the departmental road organization according to the desires of the department concerned.

The "chemins," or regional roads, are of three classes, viz: turnpikes (chemins vicinaux de grande communication) which connect the communes with the chief city of the department, (b) intercommunal roads (chemins d'interet-communal) which link up the

communes with one another, and (c) neighborhood roads (chemins vicinaux ordinaires) which afford communication between the smaller villages and hamlets. These last three classes are constructed and maintained by the local highway services at the expense of the communes and, according to circumstances, either with or without financial assistance from the departmental and national governments. The total length of the national and departmental routes has changed very little during the past century. It now amounts to over 38,000 kilometers or 24,000 miles, of which 1,350 miles consist of Belgian block or brick pavement. Regional roads are constantly being improved and now total 630,000 kilometers or about 400,000 miles. In 1905 (the latest figures available), the expenditure on roads amounted to 203,435,000 francs or upwards of $41,000,000.

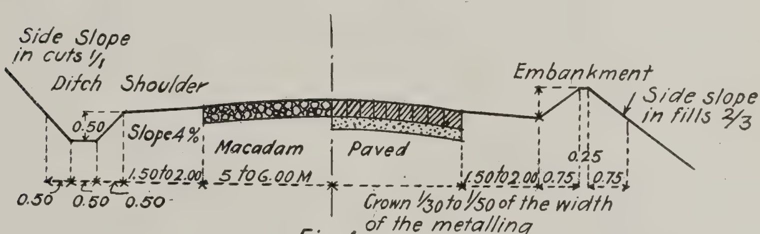


Fig. 4.
Typical Cross Section
National and Departmental Roads.
All dimensions are in metres.

This works out at $96 per mile of road, $205 per square mile and about $1 for each inhabitant.

The cross-sectional widths of these various roads are not absolutely fixed, but vary according to density of traffic, difficulties of construction, costs of maintenance and other factors. In general terms figures obtain as indicated below:

	Meters.
National trunk highways	10 to 14
Departmental trunk highways	8 to 10
Regional turnpikes	8
Inter-communal roads	7
Neighborhood roads	6

The typical cross section contemplates that the earth shoulders shall be a direct continuation of the wings of the metalled portions, though falling off more rapidly toward the side ditches. In actual practice, however, the earth shoulders are slightly higher than the

road-metalling and are provided with drainage ditches at intervals of 20 to 40 meters according to the grade, these being naturally more numerous on the steeper gradients. Special care is taken in their layout and construction. On the steeper slopes they are traced at an acute angle with the axis of the road and their mouths or intakes are given a special form to trap the water and prevent its coursing along the road.

No absolutely limiting grades have been prescribed—these depend on local topography and upon grades prevailing in each particular region. For new work 3 per cent is prescribed as a desirable limiting grade for national and departmental routes and for others 5 per cent, but under exceptional circumstances these controlling grades may be 8 or 10 per cent in the more rugged portions of France. The instructions require that curves shall, in general, be described with a radius of not less than 50 meters, though on roads of minor importance a minimum radius of 30 meters is permissible.

CONSTRUCTION AND MAINTENANCE.

In the construction of roads great care is taken to provide a firm unyielding foundation bed and to maintain it in this condition by means of an efficient sub-soil drainage system whenever local conditions render such provision advisable. These two fundamentals are given special emphasis. The thickness of metalling varies from 6 to 10 inches and is intended to permit of a reasonable loss by wear and tear without immediate resurfacing and without danger of cutting through to the sub-soil.

Maintenance of highways in France has become a veritable science based upon well-established principles supplemented by careful study of the effect of modern vehicles and the development of new materials and new road machinery. The maintenance, which is continuous, devolves directly upon the cantonniers working under the supervision of the various administrative officials. Stone is quite commonly broken by hand, although power crushers are making their appearance in the larger quarries. The material is dumped on the earth shoulders in neat pyramidal piles where it is available for patching or for complete resurfacing according to circumstances. Not infrequently the rock is handled as one-man stone from the quarry to the roadside and is there broken by hand by the assistant cantonniers or sometimes by old men who take the

job on a piece basis. A good man is expected to break 2 cubic meters a day.

Formerly the roads were maintained by a system of extensive patching by hand, but this is giving way to the more modern system of general resurfacing. Under this latter method the road is divided into sections which are attended to year by year in a regular and orderly sequence. A steam roller is allotted to a certain number of miles and moves from place to place as required, hauling behind it the driver's residence—a cottage mounted on wheels; in which he lives and as often as not rears a fairly large family.

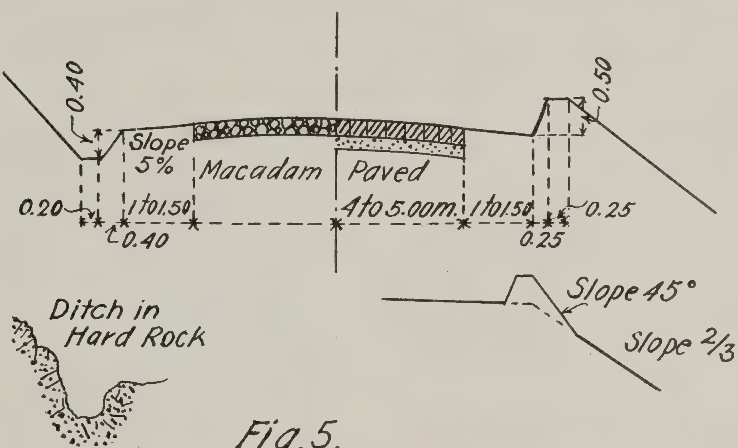


Fig. 5.
Typical Cross Section Local Roads
All dimensions are in metres.

Nevertheless, patching of holes occasioned by the presence of soft materials or for other reasons occupies a considerable portion of the cantonnier's time. They are especially skilled in this class of work, which has been given much study by the French road service, and we Americans might well profit by their experience. To determine low points in need of patching a reconnaissance is made on a rainy day, and the general contour of the incipient hole is circumscribed by an irregular rectangle marked out with a pick in the road metal. The lines of this rectangle are parallel or perpendicular to the axis of the road. When a number of holes are found near together they are all enclosed by a single rectangle. Material within the rectangle so marked is then broken out by

a pick to a depth of 3 or 4 inches, with a trench slightly deeper following the boundary of the rectangle; the broken material is removed and saved for use as a binder. It is replaced by fresh stone so handled as to bring the smaller pieces toward the edges of the patch. The old material, after raking out the larger fragments, is then spread back over the new and the whole thoroughly tamped, working from the margins to the middle of the patch. During the work the patch is freely sprinkled with water to assist in the bonding process. Traffic is also so directed as to assist in the consolidation. The foregoing is occasionally varied by making a low grade of concrete, using screened road sweepings in lieu of cement. This can be done with certain classes of stone which are naturally high in cementitious properties.

Occasionally, in order not to unduly inconvenience traffic by making large patches, the so-called laurel twig pattern is adopted. The axes of the smaller patches or "leaves" are inclined to the center line of the road, the maximum dimensions of these leaves not exceeding 3 or 4 meters in length by 1 meter in width. These patches are so placed as to leave between them (corresponding to the laurel stem) a path for the accommodation of the draft animal. It is to be remarked in this connection that almost without exception draft animals are used in tandem and not side by side as is the custom in our country. This method of haulage is particularly true of cargo vehicles though it does not apply to light carriages, stage coaches and the like.

This laurel twig pattern has not, however, been found entirely successful on roads much frequented by automobiles, due to the effect of their speed in scattering the material. In such cases, the patches are made in rectangular shapes, one meter or less in width, with the longer dimensions parallel to the axis of the road. In their unfinished state these patches are avoided by automobiles, but are traversed by the wheels of animal-drawn vehicles and are thus consolidated. The patches are made on alternate sides of the road in a rough checker-board pattern thus giving an elongated variation of the laurel twig pattern.

This method of maintenance, exclusively by hand, is falling into disuse and is now only used as a necessary means of filling holes during intervals between resurfacing. It is varied by a scheme of partial resurfacing or patching in which small rollers are used, steam or gas-propelled or drawn by horses. Generally all repair

work is done in the fall and is terminated about January 1st, after which the cantonnier keeps patches under observation and maintains the crown of the road throughout by sweeping toward the center the loose material which forms during the dry cold weather, usually in January and February.

As already stated, the method of periodically resurfacing by sections, using heavy steam rollers, is displacing all other methods.

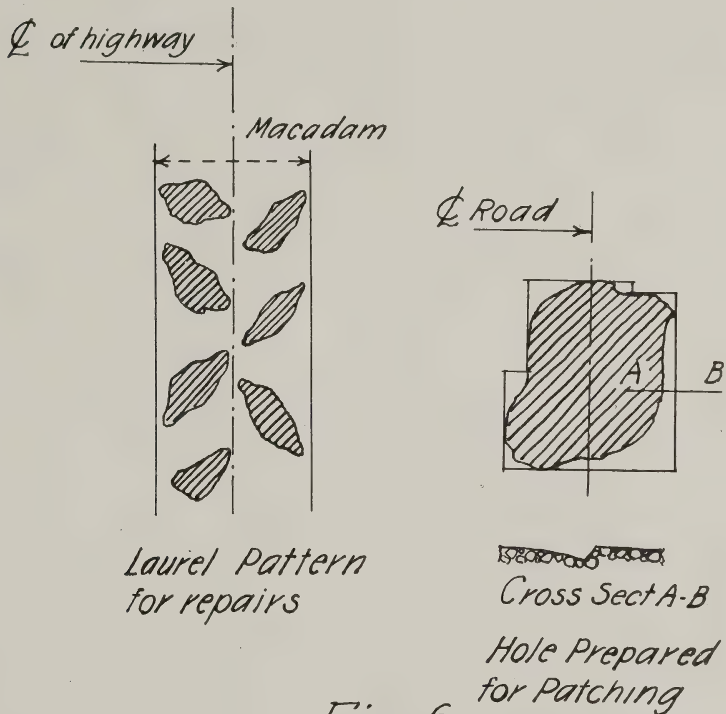


Fig. 6

It will doubtless make rapid progess hereafter due to the high cost of hand labor and the existing deteriorated state of the roads brought about by the heavy traffic of the war coupled with the shortage of labor for road maintenance during the four years that have elapsed.

In passing, it may be remarked that the French rarely scarify the roads before making repairs, notwithstanding that they have carried on extensive experiments to determine the relative ef-

ficiencies of scarifying by hand, of scarifying by lugs or spikes attached to their steam rollers as well as by ordinary scarifiers dragged by the roller or by other power. In general, when repairs are to be undertaken the old surface is thoroughly cleaned by means of stiff brooms and special care is taken to flush off detritus by heavy sprinkling. In the cities the streets are flushed by water under pressure from the mains. By this means, taking great care to clean off mud and foreign matter, the French have invariably been able to obtain a good bond between the new and the old metalling. This is attributable in a large measure to the quality of stone which they are forced to use.

Whatever method is adopted, all new work is assiduously tended until bonding is complete; all loose stones are put back and sprinkled and the patch is rerammed. Advantage is taken of wet weather to assist in the bonding.

The cantonniers are required by the terms of their employment to turn out in rain and snow storms with a view to immediately removing obstructions in the drainage systems or on the road proper. Snow must be removed at once either by sweeping, in the case of light snows, or by means of snow plow in heavier snow falls. In extreme dry weather the roads are sprinkled to prevent ravelling, while in wet weather mud is removed almost as rapidly as formed. If this mud may become useful later as a binder it is collected in piles on the earth shoulders. If not useful it is spread on the shoulders at the outer crest, or, whenever this may interfere with drainage ditches, it is hauled away and wasted on the side slopes of fills. The earth shoulders are neatly trimmed at the inner edges, weeds are rooted out, grass is cut, and in general the road is tended like a park boulevard.

ROADSIDE TREES.

A most pleasing feature of French roads is presented by the trees planted along their sides This matter is covered by official instructions with a view to securing a good standard practice throughout the country, due regard being had to differing circumstances of climate and soil. Trees are planted on either side of rights-of-way of less than 16 meters in width and two rows are planted on either side of such as exceed 16 meters. In the latter case, however, it is prescribed that the distance between rows shall be not less than 5 meters and that the trees shall be planted opposite

each other and not staggered, this in order not to obstruct access to the neighboring fields.

The advantage to be derived from planting trees along the roads is not merely a question of esthetics. Such planting, when done with due regard to local conditions, serves a number of purposes in connection with the conservation and maintenance of the road surface, the comfort of the traveller, safety under certain conditions of topography and atmosphere and finally, the intrinsic value of the trees themselves is not inconsiderable. These trees assist in conserving and maintaining the road surface by shading and thus reducing evaporation; they break the wind and prevent the surface dust from blowing away; they assist in holding the soil in place; they break the force of the current in places subject to overflow; they add to the beauty of the road and their shade is grateful to the passing traveller; they add to the security of travel by clearly defining the road and keeping animals, often hitched in tandem in long strings, from straying off the road in time of fog, rain or darkness. During the war they have been particularly useful to our motor-truck drivers who have been obliged to travel long distances at night without lights, and many a machine has been prevented by a tree from going over an embankment and becoming a total loss. To be sure, in such cases, the machine has suffered more or less and the tree has been badly damaged, if not entirely broken off, but it has generally been possible to tow the machine with its load to its destination and to put it in service again in much less time than might otherwise have been the case.

As to their financial value, these roadside trees, supplemented by those along the canals, have furnished thousands of feet of lumber and large quantities of fuel-wood during the war. In time of peace these trees are cut at regular intervals and new plantings are made, but as an emergency measure, thousands of them were sacrificed before their time for material absolutely required at the front.

An interesting variation of the value of roadside trees was demonstrated by their being felled as obstacles across the road to hinder pursuit by enemy forces, though in general they were so utilized by the Germans rather than by the Allies. They also often masked under their shade moving columns of troops and thus prevented the discovery of the latter by the aeroplane scout or balloon observer aloft. This was particularly true at night, but

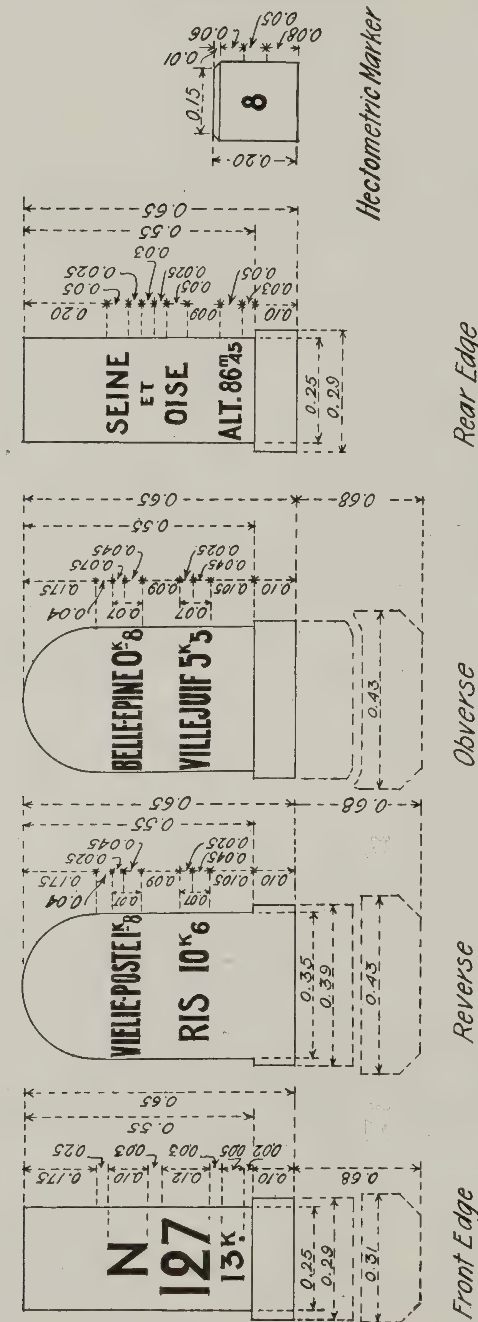
along the roads having larger trees, troop movements were often undertaken by day, the columns being halted in the shade whenever an aeroplane was sighted.

A number of species are used for these roadside plantings, among which may be mentioned the ash, the beach, the poplar, the cotton-wood, the oak and the sycamore. In certain sections fruit trees are used, but these are not approved by the Department of Public Works on account of their propensity to branch at low levels and also because of their being subject to mutilation and disease. Occasionally conifers are used, but they are generally too heavy and too somber and shade the road too much in wet weather. According to the latest figures available 10,700 miles of the national routes were planted with trees to the number of nearly three million, but as above stated these figures have been much reduced due to trees being felled by the enemy or by the Allies for military reasons.

DISTANCE MARKERS AND GUIDE POSTS.

Another very useful characteristic of French roads is offered by the system of indicating distances by large markers set at intervals of 1 kilometer and by smaller markers, called hectometric stones, set at intervals of 100 meters between the larger stones. The markings to be employed were prescribed in 1853 and held good for 60 years until in 1913, at the instance of the motor touring associations, new regulations were issued looking toward simplification and increased legibility. The kilometer posts are made of stone or cast-iron, 10 by 14 inches in plan, and stand 26 inches high above ground. Their broader faces are at right angles to the center line of the road, leaving the edges or narrower faces parallel to the road. For national trunk highways, the narrower face next to the road is marked with a large *N* and the numerical designation of the highway. Beneath the latter is the distance of the stone from the point of origin of the road, which is usually Paris or some other important center. On the broader faces are indicated the names and distances to at least two points in the direction of travel, that is, the names are on that side of the stone farthest from the places indicated, thus facilitating reading by the approaching traveller. On the rear edge of the stone is inscribed the name of the department and the altitude of the point above sea level. The intermediate hectometric stones are marked merely with the number

Fig. 7. View of guide post on French roads; the post on the right is the standard peace-time guide post at a three way road-fork, while the board at the left is especially for the guidance of army truck-traffic. The arrows have been put up for use of American truck trains.



Typical Kilometric Post All dimensions are in metres

Fig. 8.

of hundreds of meters, that is to say, the tenths of a kilometer from the last preceding kilometric marker.

Special stones are placed at points marking departmental boundary lines. The stones on departmental and communal routes conform in general appearance to those above described for the national highways. All of these stones are marked with black letters on a white background and are kept clean and legible by the cantonniers.

Guide-posts are set at all road forks and crossings. They are of a standard type prescribed in 1853 and not since changed. The tablets or guide-boards are cast iron with raised letters painted white on a dark blue background. They bear the name of the place or village at which the post is located and the names of and distances to several nearby places. With the advent of the automobile, these posts with their small lettering have become unsuitable and the various touring associations are advocating improved forms. These associations have put up their own markers to a certain extent, but permission for the erection of such special guides appears to be obtainable only with difficulty. A well-known maker of pneumatic tires has hung up at each entrance to thousands of villages a very neat sign showing the name of the place in large readable characters, and on the reverse side of each sign to be read on leaving the village is the word "Merci" (thank you) in large letters with his firm name in small neat characters. As these signs are swung with faces at right angles to the road, they are far more easily read than the government plaques placed on buildings, usually with faces parallel to the road.

However, the war with its heavy volume of truck travel by night has shown all these signs to be inadequate. The road service of each army therefore was obliged to erect temporary guide posts in its own sector, legible at long distances by day and readily discernible at night by the drivers of passing trucks who could not stop to search out the routes indicated by the smaller lettering on the standard guide posts. These war guides were large boards with white lettering on a black ground, or vice versa, and show the name of the place at which posted as well as the next important military transportation center. In many cases a number of names were shown. Whenever possible these signs were painted on buildings or garden walls at the cross-roads or forks. The French employed a large number of Tonkin-Chinese or Anamite truck drivers

and as very few of these can read, a French pilot or guide preceded their train and posted up special indicators, usually large black arrows printed on paper of various colors. A special color was used for trains of each division or to control movements made at different times, the drivers merely being told to follow the symbol of the color selected for the movement.

The American Motor Transport Corps made use of special signs to mark dangerous curves, railway crossings and the like, and for

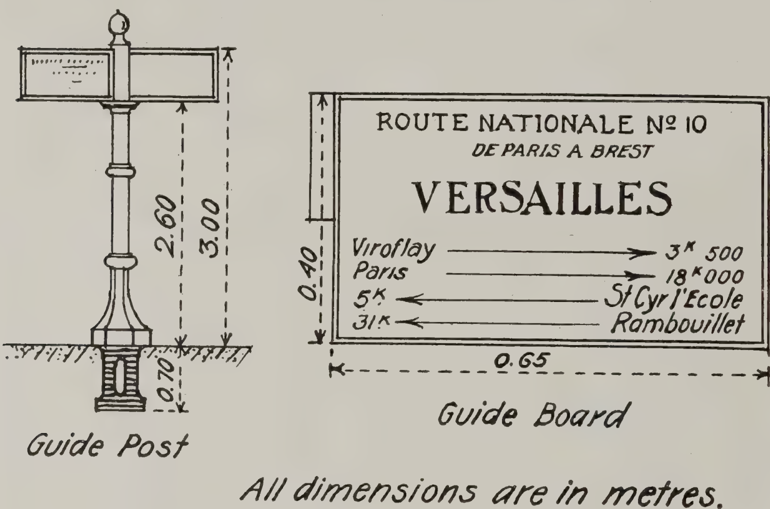


Fig. 9.

its direction guides employed arrows cut out of tin with the destination marked on the shaft. These were tacked to trees or posts by the roadside and, while very convenient to put up, they were not so useful as the larger signs.

In addition to all these signs for direction, the French road service maintains suitable markers to indicate steep descents, dangerous curves and dangerous street and highway crossings, railway grade crossings and other obstacles of which the driver should be warned in advance. Wherever traffic is heavy, railway grade crossings have been eliminated; at such grade crossings as exist, gates are placed and tended by gatekeepers who live at the crossings and are summoned by the horn of the auto. In peace times these

gates are left open except on the approach of a train, when they are closed many minutes in advance and no amount of horn blowing or other effort will cause the gate keeper—usually a woman—to "take a chance." "Safety first" and all the time, is the precept and it is rigidly adhered to. In war times for many miles behind the combat sectors the gates are habitually closed, for military trains do not run on stated schedules and may happen along at any hour; they have the right-of-way over the highway traveller and the latter must "call for the gate" in order to get through.

Constant attention is the secret of the excellence of French roads. The Corps des Ponts et Chaussées contains the best road

Fig. 10. German signs painted on wall to guide army trains on road to the east of Belfort, France.

and bridge engineering talent in France and enjoys a deservedly high reputation at home and at abroad. Its members from top to bottom devote their lives to this class of work and thus become experienced, skillful and above all patiently attentive to every detail. No break in the surface of the road is too insignificant to escape immediate attention. No development that can improve the quality of their roads or decrease the cost of construction or repair is too unimportant to escape serious study. The system of supervision and inspection by trained engineers insures the training of workmen and the proper distribution of material and effort to keep the entire system in a uniformly high state of perfection.

Notwithstanding its many admirable features, the writer does

not, however, contend that we can accept the French system as a model to be blindly followed in the United States. While the methods employed in France and elsewhere in Europe are worthy of study, the organization and administration of our system of roads must be suited to the genius of our people. National control has demonstrated its worth in Europe, and it can doubtless be applied in our own country without doing violence to our traditions or to our forms of government. Our interstate railway commerce has long been under federal supervision and during the war the control of railways and railway traffic was centralized to a degree scarcely exceeded in the areas immediately behind the fighting forces abroad. An analogous control might be well applied in a greater or smaller degree to our highway systems, insuring coördination of effort and an economy in expenditure. Federal aid would logically follow in the wake of federal supervision. Legislation to this end has been enacted and other bills are now under consideration.

It goes without saying that the particular type of road to be constructed will depend upon many considerations unlike those that obtain in France. In any event, and without waiting for the attainment of the ideal, it behooves us in the United States to put our roads on an efficient, economical and businesslike basis. The possibilities of the motor truck have been demonstrated during the war both in the United States and in Europe and with the standardization of types and the increasing ease with which repairs may be made, motorized cargo vehicles will be used in ever-growing numbers. Our roads must, therefore, be constructed and maintained to keep pace with new developments in transportation.

THE TELEMETRIC SYSTEM OF HIGH BURST RANGING.

Prepared by

Lieut. Montague Blundon,
Training Section, Office Chief of Engineers.

INTRODUCTORY.

In the May-June number of this magazine there appeared an article on High Burst Ranging, in which was given a summary of the operations, relative to the subject, in the A. E. F., together with a general description of several of the various methods that were in vogue. Mention was made of the attention devoted to this form of indirect ranging by the Flash Ranging Sections of the Engineers, and although, for various reasons, the Engineers never employed the Telemetric System, it has been generally admitted to be the method of greatest refinement and accuracy.

The Telemetric System, by virtue of its detailed refinements, is lacking in being a satisfactory method, but, so far, no other method has been brought forth which in other ways meets the requirements. Undoubtedly, actual ranging tests will bring out many important points for consideration, but, at the present time, it seems that this system will furnish an excellent basis for the study of the theoretical principles involved in all methods of high burst ranging, whether to be employed by the Engineer Flash Sections or by other observation and ranging units.

Before attempting any detailed explanation of the theory and practice of the Telemetric System of High Burst Ranging, it may be of interest to state briefly its development and mention its organization and employment by the ranging units of the A. E. F.

It seems that when the value of the indirect method of ranging was grasped and appreciated by the Allied Armies—having noted the excellent results obtained by its use on the part of the Germans—there quickly developed several lines of theoretical research, diverging to a rather marked extent in the methods of obtaining actual results.

For the most part, the English seem to have adhered to the False Angle of Site method, while the American Flash Sections[1] directed their efforts more to Ranging on the True Trajectory. The Tangent Reticule method does not seem to have proven very popular with any of the allied ranging units, although very good results were obtained from it by the French S. R. O. T.[2] groups, and, too, the American Field Artillery made study of its employment.

The French, however, true to their well merited fame as master artillerists, were by no means satisfied with any system in which there seemed opportunity of eliminating errors of observation and of computation. Their research students therefore devoted their keenest attention to the mathematics involved and finally brought forth the most refined of all methods that has so far appeared, and the one generally admitted to possess the greatest degree of precision—*le systém Télémétrique.*

In developing their ranging operations, the Coast Artillery adopted the Telemetric System and detailed a group of officers to the French Telemetric School to study the theory and practice. When these officers had completed the course they formed the teaching staff for a special Telemetric High Burst Ranging School, for both officers and enlisted men, at the Heavy Artillery School of Angers.

With the development of high burst ranging, on the part of the Flash Sections of the Engineers and by the Coast Artillery, it soon became apparent that some division would have to be made in the assignment, on the part of the Artillery Information Service, of such ranging operations. This resulted in alloting to the Flash Sections the ranging for the lighter field guns, while the Coast Artillery was to furnish its own ranging units for the Heavy Artillery. Such an arrangement naturally necessitated a certain amount of liaison between these ranging units, and with the purpose of facilitating such coöperation two Engineer officers were detailed from the Flash Sections to study the Telemetric System at the School at Angers, and then to join the First Provisional High Burst Ranging Section, attached to the 30th Brigade, R. A. R., with its P. C. at Belleville, just to the north of Verdun.

---

[1] 2nd Battalion, 29th Engineers (Flash and Sound Ranging Sections), after the armistice changed to 1st Battalion, 74th Engineers.

[2] Section de rechérché de renseignements par observation terrestre—information service employing terrestial observations.

This section consisted of three independent bases, under the command of Capt. Walter Hall, C. A. C., with a first lieutenant in charge of each base. The observation posts, two to each base, were located on the outlying hills of this renowned sector, and one post, in particular, occupied Fort Douaumont, made so justly famous in the defense of this gateway to Paris.

These posts were installed in small demountable portable houses, over which the common chicken-wire camouflage was spread —giving the false contour effect. A vertical and horizontal type of observing instrument was mounted, in each post, on specially constructed tables, and, following out the method of the system, each end of a base was located so that reciprocal sites for orientation might be taken between them.

The section got into position, with a very good determination of its O. P.'s, just about two weeks before the Armistice, and although three efforts were made to range guns of the R. A.R., no actual results were obtained. In the first two cases the adjustment was attempted for an American battery of 19 G's, but the visibility was exceedingly poor, and, although in the second trial the battery commander had posted his own observers who verified the actual bursting of the shells, no bursts could be seen from the Telemetric Stations.

In the third trial the adjustment was attempted for a battery of 164 mm. French naval guns. In this trial, however, the French S. R. O. T. station reported the fire to be percussion shots—showing conclusively, of course, that the fuses did not function as time bursts. It should be mentioned here that there were two types of fuses available to produce bursts upon the trajectory, but comparatively few batteries were equipped with them. These were the "L. D." fuse, with a maximum time interval of 52 seconds, and the "L. D. A." fuse with a maximum of 70 seconds. Both types were suitable for shells of all sizes, except the 75 mm. field piece and the 14-inch American naval guns which were operating along this section of the front. Besides the lack of fuse equipment by many batteries for which adjustment might, otherwise, have been made by the Telemetric Section, other organizations were lacking in prolongation abaques for the particular type of shell, powder charge, etc., supplied to the batteries. These abaques furnish the data required in this particular method of ranging by high bursts, and further comment will be made concerning their use later on in the theoretical discussion of this article.

During these latter days of the War, it will be recalled, the lines were moving rapidly forward, and a reconnaissance had been made for the purpose of moving the section very much nearer the lines, when all such moves were stopped by the signing of the Armistice.

In treating of the theory and practice employed in the Telemetric System the discussion is given under the following captions: General Outline of System, Instruments, Theory, Operation, Comment.

GENERAL OUTLINE OF SYSTEM.

As in all operations pertaining to accurate ranging, the Telemetric System presupposes precise locations (coördinates) of observation posts, guns and target, together with coadjusted orientation. The theory is based on the employment of only one base—two observation posts, each post being equipped with a horizontal and vertical type of observing instrument. In practice, however, it is most desirable, for purpose of a check, to employ at least two bases in observing bursts.

Each post is in telephonic connection with a central—where all of the computations, plottings and adjustments are carried out—and which, in turn, is in communication with the batteries; only observers and telephone operators occupying the posts. Owing to the general organization of the sections, their function is more for relatively stabilized than mobile operations; their mission is for the General Reserve of Heavy Artillery (A. L. G. P.), and not for the quickly manœuvring field guns. The operations incident to installing a base are very refined and necessarily consume much time, though the argument is advanced that a section should always be able to complete its orientation and be prepared for ranging within less time than required for the larger guns to get into position. Nevertheless, they can never be considered units as mobile as the Flash Sections.

The method of adjustment is based upon the determination of a fictitious point of burst, clearly in the field of view of the observation instruments. All elements relative to this fictitious point are determined in advance of the adjustment, and its location is computed with the same precision as if the point were an actual visible object; for example, a balloon. The data necessary for the location of this point are the co-ordinates, height above the initial plane, the distance of its horizontal projection from the target, and

the gisements[1] and distances from the observation posts. The battery is furnished with the data enabling it to adjust the firing so as to cause the bursts to take place near this predetermined point —toward which the observation instruments are directed.

The observation instruments being clamped along the line of site toward this fictitious point of burst, remain in this position throughout the adjustment, and the deviations of the actual bursts are read, in centigrades, both horizontally and vertically, in the subscales of the telescopes—from this fictitious index point. Data is thereby obtained for defining the particular trajectory on which the actual bursts have occurred, and with this information at hand the *prolongation of the trajectory* can then be computed, and the *theoretical point of impact* for each burst determined. This, in turn, gives the information sought—the deviations in ''rights and lefts, longs and shorts.''

This method of high burst ranging may, therefore, be defined as—the observation and determination of the position of a shell-burst, in air, near a predetermined fictitious point on its trajectory; and the computation of the prolongation of this trajectory to its theoretical point of impact, in relationship to the target.

With well trained sections it is considered that the initial data required for an adjustment should be prepared within 30 minutes; and, after the bursts are observed, the results should be submitted to the Battery Commander within 5 minutes. This statement is based on the experiences of both the French and American personnel. It must always be borne in mind, however, that a Telemetric Section should be a highly trained specialized unit, the sole mission of which is merely the adjustment of fire by means of observations on high bursts, and the purpose is decidedly not to use the posts for any other form of observations, as, for instance, in the case of the employment of the Flash Sections, in addition to ranging, for the collection of all information pertaining to the enemy's works and movements.

Relative to the time consumed in obtaining actual results from this particular method of high burst ranging, a quotation is submitted from the French document issued from Reserve General d'Artillerie, 3rd Bureau, under date of June 14, 1918, entitled

---

[1]Gisement—the horizontal angle which the line makes with Lambert North-Y-line.

"Reglage Par Coups Fusants Hauts avec Section Télémétrique"; the translation being as follows:

"It is of great importance to maintain to a high degree:

On one part, the training of the observers;

On the other part, the training of the computers and telephonists.

"During the fire of the 21st of May (1918), the time necessary to convey to the battery the results of a salvo was approximately 15 minutes. On the 24th of May, this time had been reduced to 6 or 7 minutes, due to a more methodical handling of the personnel.

"It may be stated that, with a well trained personnel, the result of a salvo of 4 shots should be given to the battery in 4 or 5 minutes after the firing of the last round of the salvo.

"It should be noted that the method of fire by salvos is, in all cases, particularly advantageous from the point of view of 'lost time.' The observations made upon a burst are immediately transmitted to the central computing station, without resulting in inconvenience for the observation for additional rounds; the operations relative to the prolongation of the trajectories are started at the time of the firing of the salvos."

INSTRUMENTS.

As mentioned before, each post is equipped with a direction and elevation type of observing instrument. These are very much the same in pattern, except for the graduations on the reticules of the eye-pieces, and the direction instrument has, in addition, a special telescope and a horizontal silver circle for setting off the gisement to the predetermined point of burst. These extras are for more precise means of setting off the gisement—the elevation instrument not requiring the same degree of refinement in orientation.

The graduations on the horizontal plates of both instruments are in grades, at 2-grade intervals, from 0 to 200, in both directions. Readings counter-clockwise are +, clockwise —. The graduations on the silver circle are of three lengths: full lengths, corresponding to 10 grade divisions; ¾ lengths, to 2 grade divisions; and ½ lengths, to 1 grade divisions.

The telescopes are of the well-known Longue Vue Monoculaire á Prismes style, Type X, fitted with three different power eyepieces, mounted on a "revolver." The night lens contains a device for illuminating the reticule eyepiece. There is also provided a series of colored screens; and an extra attachment is provided for training observers in reading simulated bursts.

There are three brass plates provided for the base leveling screws; one plate being slotted, one with a hole and the third

smooth. These are screwed on the permanent table, in place of the usual tripods, on which the instruments are mounted.

There are trunnion and telescope leveling bubbles on each type of instrument, and, in addition, a prism and mercury bowl are provided for making the instruments truly horizontal. Detail printed instructions accompany each set of instruments, and these explain fully the various adjustments in self-collimation, leveling and orientation.

The two types, direction and elevation, are shown in Figures 1 and 2, page 551.

THEORY.

Before treating of the theory involved in the actual ranging operations mention should be made of the form of computations employed in the orientation, in order, especially, that the terms employed in the process of ranging may be made clear.

Counter gisement (represented by the letter V) is the basis of angular measurement in the telemetric system; the angle being measured counter-clockwise from Lambert North. The deviation (less than 100 grades) from the Y-axis is represented by the letter W, and the distance between two points is represented by the letter D.

A *Telemetric Base* has two observation posts, looking toward the target, the right-hand post is designated T_1, and the left-hand post T_2, the base distance being represented by B, and the coordinates by a_1 b_1 and a_2 b_2.

After orientation is completed the angles are referred to a *Directing Line*—perpendicular to the base, toward the target, the gisement of which is represented by V_0.

α and β represent the co-ordinates of the predetermined fictitious *Point of Burst,* Ω, the telemetric elements of which are θ_1 and θ_2—the angles at T_1 and T_2 between the *Directing Line* and the lines of site to Ω; the distances of site are represented by A_1 and A_2, and the gisements by V_1 and V_2.

θ_1 and θ_2 may be either positive or negative, but are always less than 100 grades. If the *Directing Line* should have to be rotated in a positive direction (counter-clockwise) in order to bring it on the line of site from the T station to Ω, the angle θ is positive, and if the reverse operation should be required θ is negative.

p represents the parallax of Ω with respect to T_1 and T_2, and its value is always considered positive. From a reference to the ac-

companying figure (Fig. 3, page 552), the following formulæ can be obtained:

$$\theta_1=(V_1-V_0)\ ;\ \theta_2=(V_2-V_0)\ ;\ p=\theta_1-\theta_2$$

The method of reading the horizontal angle to the burst may now be considered. In the reticule forming the subscale, in the focal plane of the telescope, of the direction instrument, is a series of vertical lines graduated in centigrades, right to left, from 0 to 200. The graduation 100 is in the center of the line of collimation of the telescope. It has already been mentioned that the plate of this instrument is graduated in grades, 0 to 200, right and left from the index point, and the problem is one of determining the method of directing the telescope toward the fictitious point of burst, and of reading the deviations of the actual bursts; the procedure is as follows:

The telescope is first directed so that when the index point reads 0, its principal axis is along the *Directing Line.* The angle θ is computed in grades and centigrades, but as only the nearest grade P can be set off on the plate, the remainder of the angle, in centigrades, must be read at some division M on the reticule. Fig. 4 explains the principle, and the following equations can, therefore, be formed. These hold true for all values θ and P, whether positive or negative: $\theta_1=P_1+(M_1-100)$; $\theta_2=P_2+(M_2-100)$.

θ_1 and θ_2, having been computed, are known, and the values of P_1 and P_2, being the nearest full grade values corresponding to θ_1 and θ_2, are also known, so that the equations are really solved for M_1 and M_2—the two reticule readings to Ω.

It has been assumed so far, however, that the graduations on the subscale and on the horizontal circle are correct, but this is seldom the case, and the readings should be compensated. The sub-scales in each set of instruments are, by photographic selection, compared until a pair is found as near as possible to be identical. These are selected for the instruments in a single base.

On the sub-scale 200 divisions will, then, really correspond to 200 centigrades plus a correction, represented by $2\,t$ (with proper sign), and the correction is assumed to apply uniformly to the graduations. The true value of M divisions is, therefore, $M\left(1+\frac{t}{100}\right)$; where t is the coefficient of compensation for the instrument, and may vary from -2 to $+2$, being expressed by t per cent.

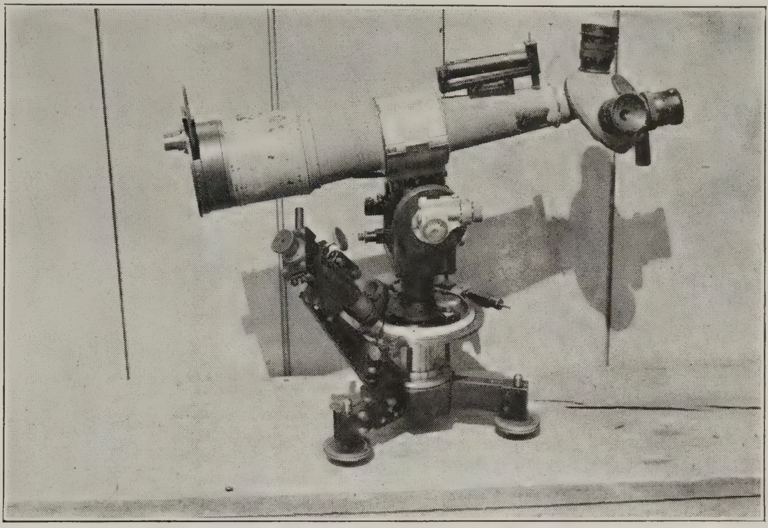


Fig. 1.

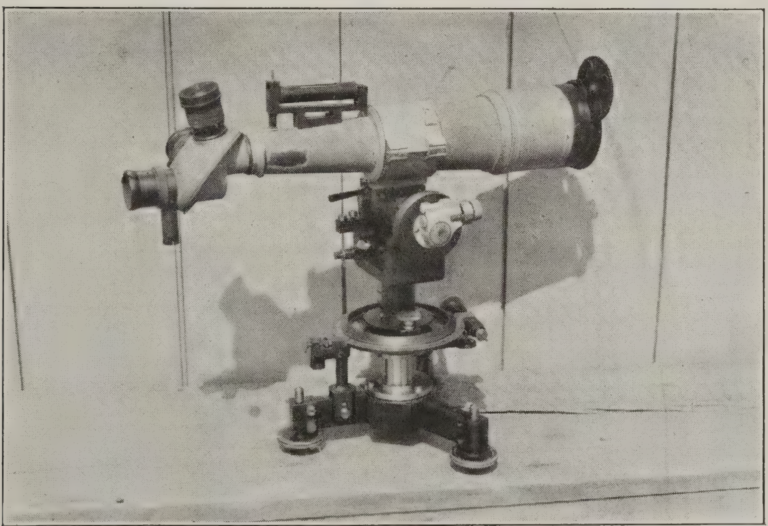


Fig. 2.

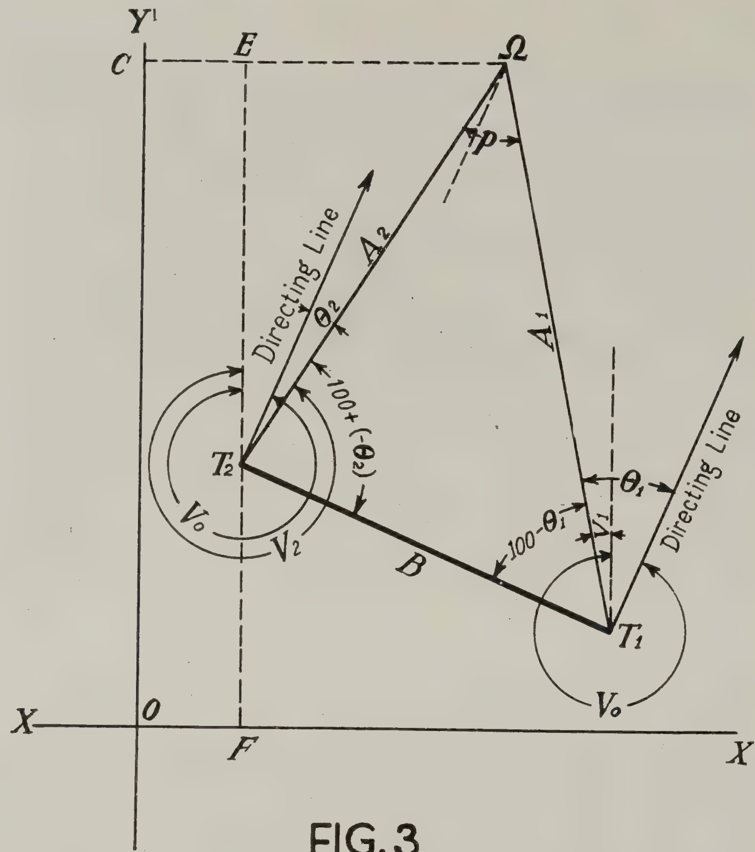


FIG. 3

The following model is used in the computation:

$a =$	$\beta =$	$a =$	$\beta =$ ....
$a_2 =$ ———	$b_2 =$ ———	$a_1 =$ ———	$b_1 =$ ———
$a - a_2 =$	$\beta - b_2 =$	$a - a_1 =$	$\beta - b_1 =$ ......
Log $(a - a_2) =$		Log $(a - a_1) =$	
colog $(\beta - b_2) =$ ———————		colog $(\beta - b_1) =$ ———————	
log tan $W_2 =$		log tan $W_1 =$	
$W_2 =$	$V_2 =$	$W_1 =$	$V_1 =$ ......
	$-V_0 =$ ———		$-V_0 =$ ———
	$\theta_2 = \pm$		$\theta_1 = \pm$ .....
			$-\theta_2 = \pm$ ——
			$p =$ ....

For the error of calibration of the plates the values of P *net* are given for the different readings of P.

The fictitious point of burst Ω is taken in the vertical plane, through the gun C and the target O, *near* which the actual burst E, used to adjust the fire, will take place. The gisement of the gun-target line is represented by V_0, the co-ordinates of gun being x_0y_0, and of the target xy. The height of Ω, above the initial plane, is represented by H_Ω, and the distance of the horizontal projection

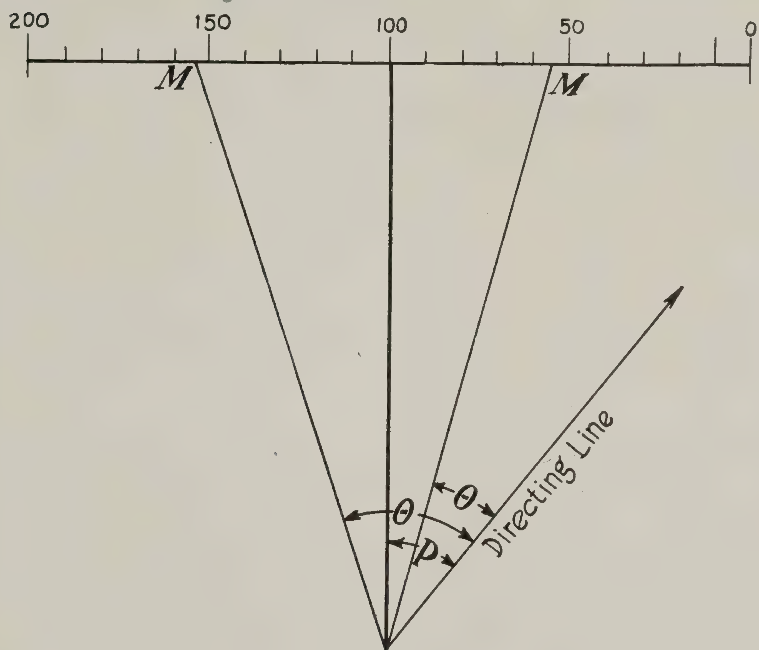


FIG. 4

of Ω from the target is represented by Q. The height and distance are therefore functions of the particular trajectory to be employed in the adjustment, and knowing either of these values it will, later on, be shown that the other may be graphically obtained. Assuming, therefore, that the distance Q is known, the coordinates $(\alpha\beta)$ of Ω can either be scaled or computed. The various elements of Ω are shown in Fig. 5.

Having determined the co-ordinates of Ω, the gisements from the two T stations are computed and the observers are given the

deflections, from the *Directing Line,* P on the plate and M on the sub-scale, in order to look for the burst. The directions of the telescopes are not altered during the adjustment, but, when necessary, the fuse length is changed so that the bursts may occur in the field of view. The observers read the burst E on the divisions of their sub-scales at M'_1 and M'_2, and the problem becomes one of plotting the horizontal projection of the burst on a chart, where is shown the direction V_0, and the points Ω and O.

The elements for any burst E are θ'_1, θ'_2 and p', and the increment of change is represented by d, so that the following relationships exist—

$$d\theta_1 = \theta'_1 - \theta_1;\ \ d\theta_2 = \theta'_2 - \theta_2;\ dp = p' - p;\ p' = \theta'_1 - \theta'_2.$$

Also, since during the adjustment P_1 and P_2 remain constant, the following are derived: $-d\theta_1 = M'_1 - M_1$; $d\theta_2 = M'_2 - M_2$; $dp = d\theta_1 - d\theta_2$.

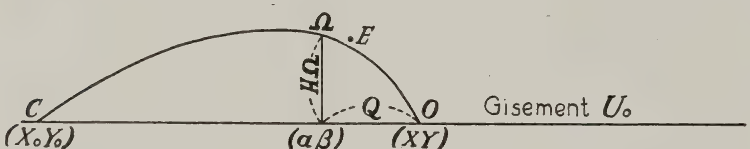


FIG.5

In Fig. 6 a circle is described through the posts T_1, T_2, and the fictitious point of adjustment Ω. The Directing Line from T_2 intersects the circle at L, and a line, LL_1, is drawn through L and Ω. The angle T_1T_2L is, by construction a right angle, and the arc $T_1\Omega L$ is a semi-circumference; and, therefore, the angle $T_1\Omega L$ is a right angle. If, at Ω, the line LL_1 is rotated through an angle equal to θ_2, its new position, RΩT, will be tangent to the circumference at Ω; for the angle θ_2 is measured by ½ arc at LΩ, and in the rotation the whole of this arc has been passed over.

All points along the circumference have the same parallax p, but for a limited extent around Ω we may consider with very little error, that the tangent at this point is identical with the circumference, and that the locus of points of equal parallax will be the tangent.

The line $T_1\Omega$ is the locus of all points with direction θ_1 from T_1; directions are considered positive from T_1 towards Ω; and, on LΩ, positive directions are considered from left to right—for both cases opposite directions are considered negative.

In Fig. 7, E is the actual burst, and L′ the point where the *Directing Line* from T_2 intersects the circle passing through the posts T_1, T_2 and E; Ω' is the intersection of this circle with the line of site from T_1 to Ω. In the same manner, as at Ω, the line $L'\Omega'$ is rotated about the point Ω', through an angle θ_2+dp, to the

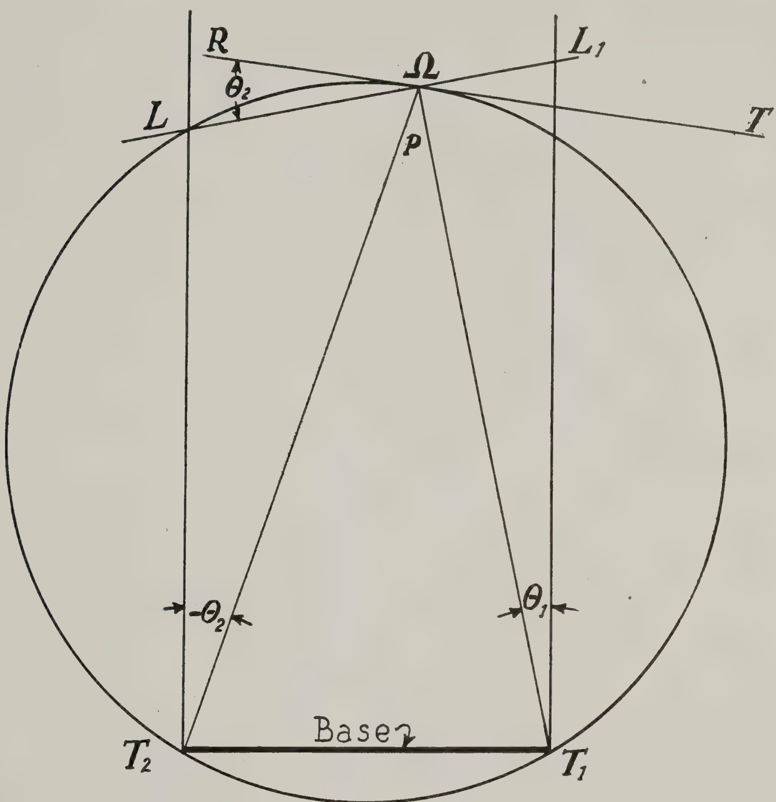


FIG. 6

position $R'\Omega'T'$, tangent to the circle at Ω'. But dp is small, never over 1^G, and $\theta_2 \pm dp$ is practically equal to θ_2, and the tangent at Ω' is for all practical purposes parallel to the tangent at Ω, and the former may be considered the locus of all points of parallax p'.

In the triangle $E'\Omega T$, $\tan d\theta_1 = \frac{E'\Omega}{T_1\Omega}$: but $T_1\Omega$ is the distance to

the fictitious point of burst, represented by A_1, and since the tangents and sines of small angles are almost equal, the substitution $E'\Omega = A_1 \sin d\theta_1$ can, with little error, be made. Also, since the sines of small angles are very nearly proportional to the angles themselves, $\sin d\theta_1$ can be written $\sin 1^{\backprime} d\theta_1$ (sine 1 centigrade mul-

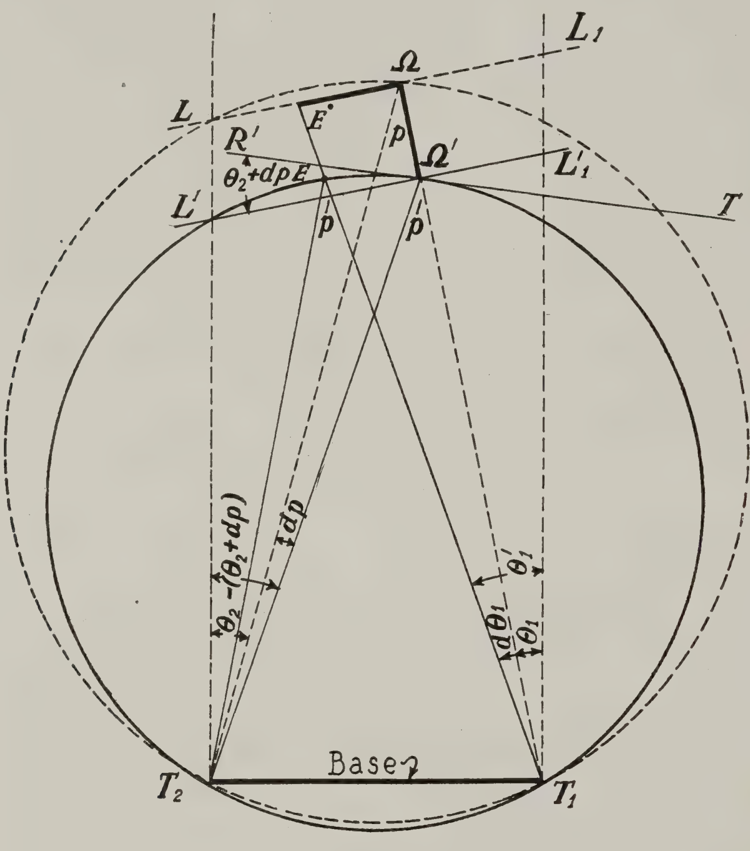


FIG. 7

tiplied by $d\theta_1$), and the relationship is, $E'\Omega = A_1 \sin 1^{\backprime} d\theta_1$. The value $A_1 \sin 1^{\backprime}$ is constant for any one shoot, and is called the *lateral sensitiveness* of Ω with respect to the station T_1, or the lateral displacement from Ω for a variation of 1 centigrade in the value of θ_1. This constant is represented by σ_1, and in a similar way $\sigma_2 =$

$A_2 \sin 1^\backslash$; and the above expression is therefore written $E'\Omega=\sigma_1 d\theta_1$.

In the triangle $T_2\Omega\Omega'$, the following proportion is found: $\frac{\Omega\Omega^1}{T_2\Omega^1}=\frac{\sin dp}{\sin p}$; or $\Omega\Omega'=\frac{T_2\Omega' \sin dp}{\sin p}$; but $T_2\Omega'$ is practically equal to A_2, and $\sin dp$ may be written $\sin 1^1\, dp$; therefore $\Omega\Omega'=\frac{\sigma_2}{\sin p}\, dp$. The value $\frac{\sigma_2}{\sin p}$ is, also, a constant for any one shoot and it may be represented by ρ_1, which is called the *longitudinal sensitiveness* of Ω with respect to the station T_1, or the *longitudinal displacement*

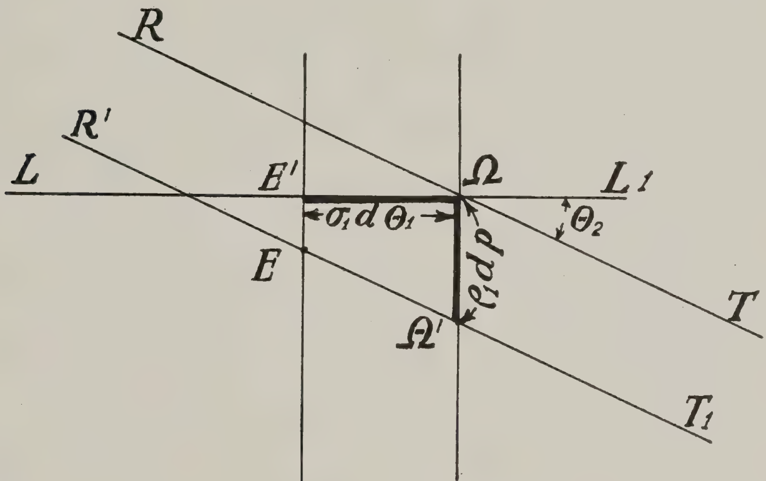


FIG. 8

of Ω, relative to the line of site from T_1, for a variation of one centigrade in parallax. In a similar way $\rho_2=\frac{\sigma_1}{\sin p.}$ The expression therefore becomes $\Omega\Omega'=\rho_1 dp$.

In the immediate vicinity of Ω the lines of site for T_1 to the points of burst may be considered parallel, and are called *parallels of direction;* while the tangents, also considered parallel, are called *parallels of parallax.*

In figures 6 and 7, it will be noted that the relative displacements of E from Ω are very much greater than would be the case under actual ranging conditions, the deviations having been exag-

gerated in order to present the relationships. The statement in the above paragraph may, with respect to lines in the immediate vicinity of Ω, be shown practically true to actual conditions by Fig. 8.

To locate any burst E, therefore, from the predetermined fictitious point of burst Ω, a chart is prepared, verticals are drawn spaced according to the value of σ_1, and diagonal lines, inclined from the horizontal by the angle θ_2, spaced according to the value of ρ_1. The expressions $\sigma_1 d\theta_1$ and $\rho_1 dp$ may now be further examined:

σ_1 and ρ_1 are constants and their values are determined by graphical scales. As stated above $d\theta_1=\theta'_1—\theta_1=M'_1—M_1$, or the *difference* between the subscale readings from T_1 station, for Ω and for any burst E. Also $dp=d\theta_1—d\theta_2=(M'_1—M_1)—(M'_2—M_2)$; or, the *difference* in the subscale, readings to any burst, between T_1 and T_2 stations. The expression may, however, be written $dp=(M'_1—M'_2)—(M_1—M_2)$; Ω is, therefore, plotted by $d\theta_1=M_1$, and $dp=(M_1—M_2)$.

In the example given at the end of this article $M_1=75$, $M_2=73$, and $M_1—M_2=+2$; $\sigma_1=0.878$, and $\rho_1=2.917$; $\theta_2=53.^{G}—26.6'$. The graphic chart is prepared to a scale (1:2000, or 1:5000) laying off verticals to a horizontal line, spaced 10 σ_1's and lines inclined by the angle θ_2, spaced ρ_1's. The gun target line is drawn through Ω inclined to the vertical $T_1\Omega$ line by the angle $\psi_1=U_0—V_1=370.^{G}—10'—394.^{G}—21'=24.^{G}11$. Fig. 9 shows the construction of this graphic chart. The first shot in the example, $M'_1=76$, $M'_2=80$, $M'_1—M'_2=—4$, is plotted and the deviations, *da* and *de*, are found to be +18 and —7.

So far, only the horizontal projections of the bursts have been considered, and it is necessary to determine the heights of bursts in order to prolong the trajectories to the points of impact.

The correction for curvature is expressed by the formula, $S=\frac{D^2}{2R}$, which is always a positive quantity; D being the horizontal distance, and R the radius of the earth, or $S=0.008\,D^2$. The correction for refraction (N) is given by the formula $N=\frac{D}{R}\,m$; where m is the coefficient of refraction, taken as 0.089. The combined correction for curvature and refraction is, then, $S+N=.066\,D^2$.

The following symbols are used to denote the elevations of the principal points:

Z_0=Elevation of Gun;
Z=Elevation of Target;
C_1=Elevation of Station T_1;

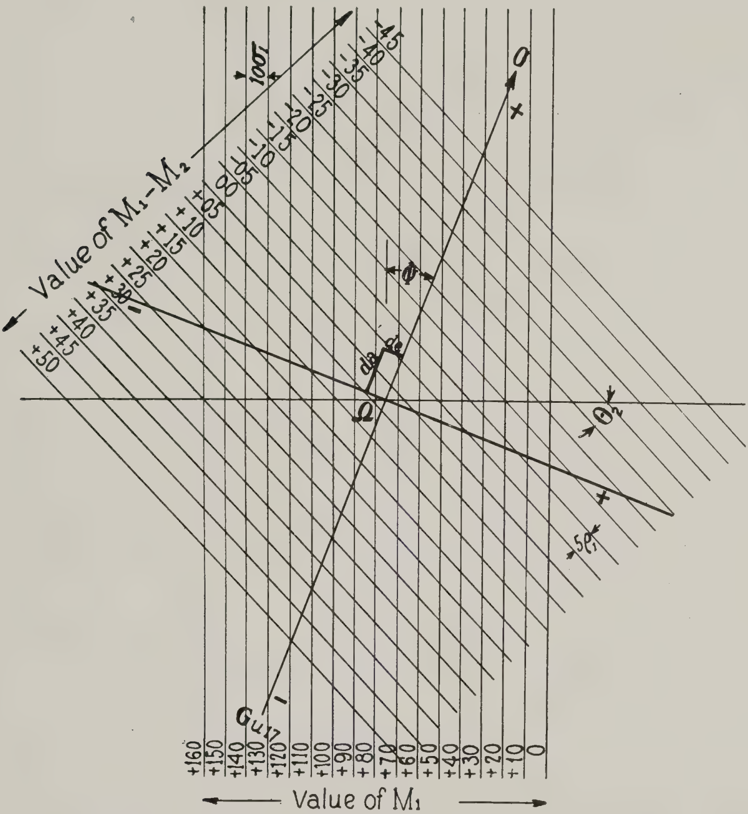


FIG. 9

C_2=Elevation of Station T_2;
K′=Difference in Elevation between Gun and Target;
J_1=Difference in Elevation betwen Gun and T_1;
J_2=Difference in Elevation between Gun and T_2.

Fig. 10 shows these relationships relative to gun and target, and $K' = Z - Z_0 - 0.08\ D_0^2$.

Fig. 11 shows the relationships of the horizontal planes through the T_1 station, gun and target, and the following formula is obtained,

$$J_1 = K' + (C_1 + 0.066 A_1^2 - Z).$$

And, in a similar way,

$$J_2 = K' + (C_2 + 0.066\ A_2^2 - Z)$$

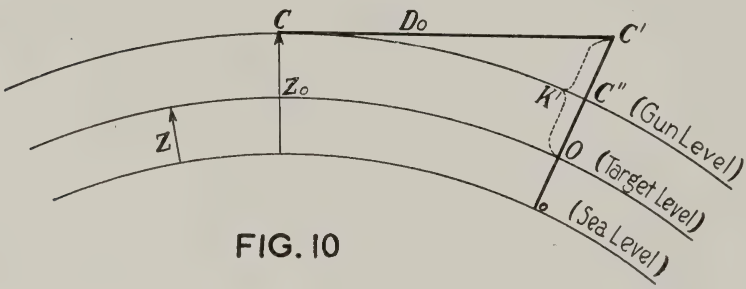


FIG. 10

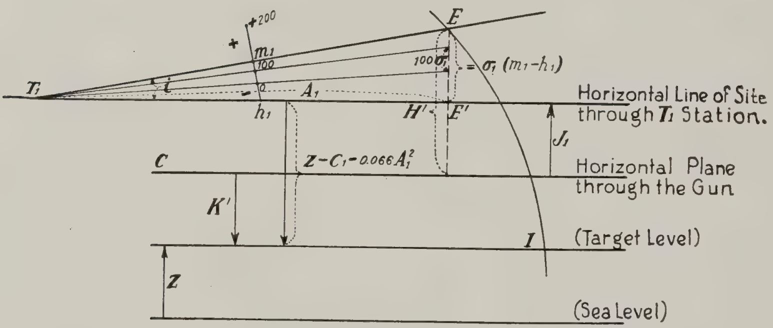


FIG. 11

H′ represents the height of burst above the horizontal plane of the gun and (Fig. 11) $H' = J_1 + E'E$; but $E'E$ is the actual height of burst above the horizontal plane of site corrected for curvature and refraction, or the value of the angle i.

In order that the elevation instrument may be pointed so that the line of collimation to Ω may pass through the 100-mark of the subscale the horizontal line of site will be at a distance $-h$, below the 0-mark. In Fig. 11, $E'E = A_1 \sin i$, but $\sin i$ may be written $\sin 1^\backslash\ (m_1 - h_1)$; therefore $E'E = A_1 \sin 1^\backslash\ (m_1 - h_1)$. But, as

already mentioned, $A_1 \sin 1' = \sigma_1$; therefore $E'E = \sigma_1 \ (m_1 - h_1)$ and substituting in the above equation, we have:

From Station T_1 $H' = J_1 + \sigma_1 \ (m_1 - h_1)$

From Station T_2 $H' = J_2 + \sigma_2 \ (m_2 - h_2)$.

Under any given conditions of fire H' and m are the only variables, and the equation is therefore that of a straight line. A chart is prepared on which this line is constructed, from rectangular axes, representing values of H'. The values of m are plotted as abscissæ (1 mm.=1 centigrade) and values of H' (1 mm.=2 meters) as ordinates. The slope of this line is σ, and is found by laying off 100 m. as abscissa, and 100 σ as ordinate. The line from this point to the origin will then be parallel to the line representing values of H'. The elevation angle to Ω being known, h can be assumed equal to m, then, $H' = J_1$, and this value of h can be laid off as abscissa, and the value of J, as ordinate, and the true line will pass through this point, and will be parallel to the line through the origin, with slope σ. The reading to Ω corresponds to $m=100$ on the vertical subscale, and the height of Ω (H'_Ω) can be read as an ordinate corresponding to this abscissa.

A similar curve should be constructed for T_2 (on the same chart), and a slightly different value for H' will be obtained, but the larger value should be adopted. For an approximate value, however, the following empirical formula may be used—

$$H'_\Omega = 1.03 \ \sigma_1 \ (100 - h_1) + C_1 - Z_0.$$

Fig. 12 indicates the method of constructing the line for values of H'. The chart is used in conjunction with an abaque (Plate I) which is constructed on the following principle:

The quadrant angle of departure (ϕ) and the angle of fall (ω) being functions of the range, these elements are plotted for curves representing the prolongation of trajectories. Ranges are laid off as abscissæ (1:20,000) and values of ϕ and ω are used as ordinates (1 mm.=6 minutes). As the angle of fall is always greater than the quadrant angle of departure, for the same range, the curve representing angles of fall is constructed above the quadrant angle of departure curve. Two additional curves for angles of fall are plotted; the upper one corrected for a head wind component of 10 meters per second, and the lower one for the same wind component from the rear. Other wind component values are interpolated.

On the same abaque, with the same axes, are plotted values of angles of fall as ordinates, and abscissæ corresponding to distances of the horizontal prolongations of trajectories, for heights of bursts for even 50 meters.

The lower part of the abaque shows the *lateral* displacement for the prolongations of trajectories. The abscissæ are ranges (1 : 20,000) and the ordinates are lateral deviations in meters (1 : 5,000) to the left above the x-axis, and to the right below.

In Fig. 13, E represents the point of actual burst, and H′ its height above the initial plane, I the theoretical point of impact, and

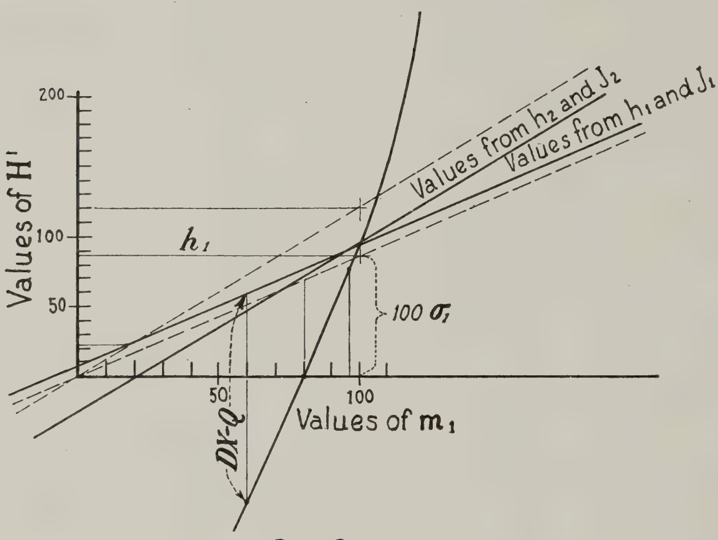


FIG. 12

K′ the height below (or above) the point of fall, A′. dx and $d'x$ represent, respectively, the prolongations for height H′ and K′. Then, for the algebraic sum, DX$=dx-d'x$, and Q$=dx_{\Omega}-d'x$; DX—Q is, therefore, the difference between the prolongations for the point E and for the point Ω and it is the distance required, being determined from the prolongation abaque. Abaques are furnished for each caliber of gun, type of shell and fuse, powder charge, etc., and they are employed in the following manner:

Assume the quadrant angle of departure (ϕ) to be 25°, a head wind of 10 meters per second, and a height of burst for Ω to

ABAQUE FOR TELEMETRIC SECTION OF THE LONG RANGE HEAVY ARTILLERY

16cm Gun Model 91² and 93 rifled to the left - Shell F.A. Vo. = 775 m/s. - L. D. Fuse 1917

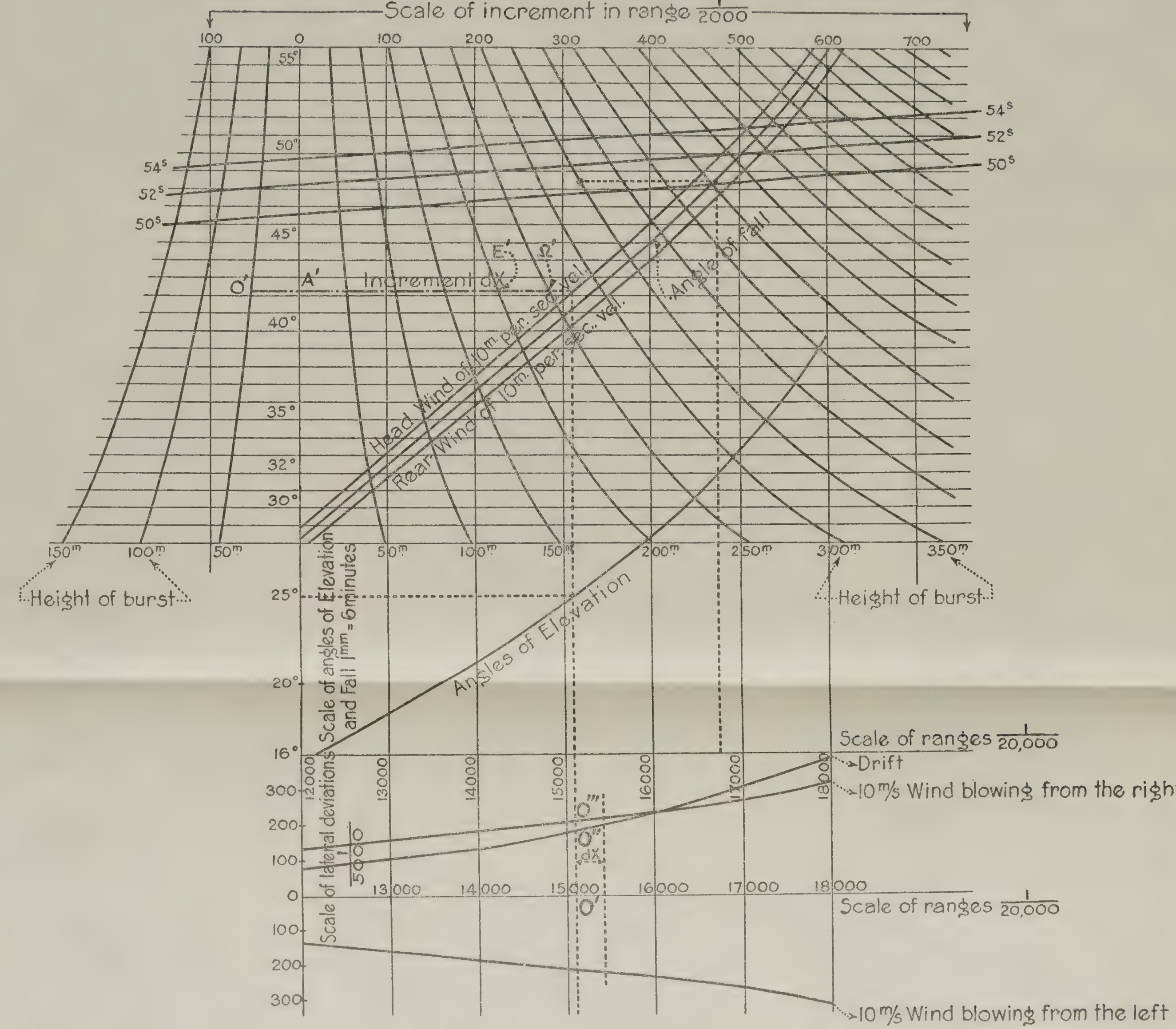


PLATE 1

be 250 meters, with the target 50 meters below the plane of the gun.

Enter the abaque with $\phi=25°$, and follow horizontally to the curve of "Angles of Elevation"; then follow vertically to the curve of "Angles of Fall," corrected for head wind of 10 meters per second, then horizontally to the curve of "Height of Burst" of 250 meters—this latter point being the horizontal projection of Ω. To find the horizontal projection of the prolongation of the trajectory for the burst this line is continued to the left to the curve of "Height of Burst" for the height of target, $K'=-50$, to the point $0'$. The distance $\Omega'A$ will then represent the increment dx_Ω, and the line $A'O'$ represents the prolongation $d'x$, while

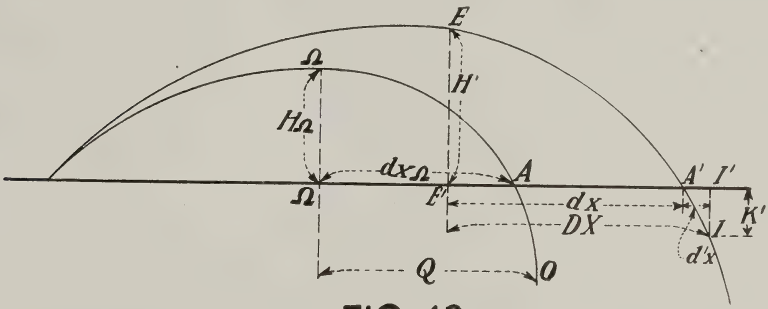


FIG. 13

the line $\Omega'0'$ represents the distance Q. So much is prepared in advance for the shoot.

If the height of an actual burst is found, for instance, to be 200 meters, the point E' will represent its horizontal projection, and the line $E'O'$ will represent the horizontal projection for the prolongation of the trajectory for this burst, equal to DX. The distance desired, however. is the *difference* between the prolongations for Ω and for any burst, or $\Omega'E'=DX-Q$.

On the graphic representation of the equation $H'=J_1+\sigma_1(m_1-h_1)$, for each value of m_1 there is a corresponding value H', and from the abaque there is obtained a corresponding value of $DX-Q$, for any particular height of burst. By assuming heights of burst, differing by 50 meters, various values for $DX-Q$ will therefore be obtained, and these may be plotted (Fig. 12) from the diagonal line, from points representing the corresponding values of H'. The result will be a curve which will indicate the value of $DX-Q$ for any reading of m_1.

There still remains to be considered the lateral deviation, caused by wind and drift, acting on the trajectory between the observed point of burst and the theoretical point of impact. These values, for drift and various wind components, can either be determined and put in the form of a reference table, or else they may be determined directly from the abaque. In the latter case, the procedure is as follows:

In the example above, for a quadrant angle of departure of 25°, and wind component of 10 meters per second from the right, follow vertically downward, from the point of intersection on the "Angles of Elevation" curve to the curves for Drift and Wind. The line $0'0''$ will then represent the lateral deviation to the left due to drift, and the line $0'0'''$, the deviation to the left due to wind. The sum of these two will then be the total lateral deviation at the

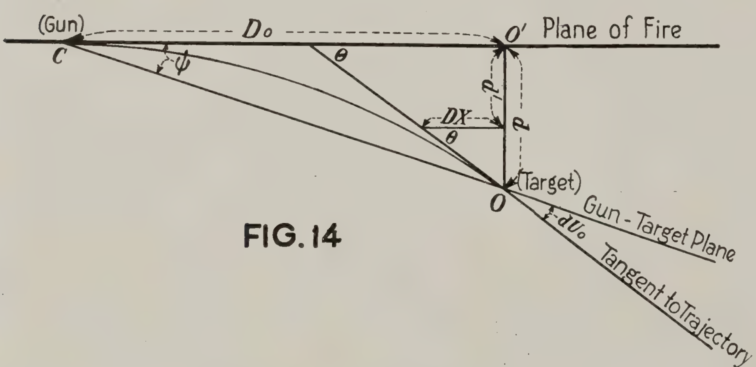


FIG. 14

target. A portion of this deviation has, however, already been obtained in the determination of the position of E with respect to Ω (*da* and *de*), so that only the amount of deviation between the point of burst and the point of impact is required, or, in other words, a certain function of DX. If dU_0 represents the angle between the gun target line and the tangent to the trajectory at the point of impact, then DX sin dU_0 will express the amount of deviation to be considered. This quantity can be written DX sin 1′ dU_0, or $DX\left(\frac{\pi}{20,000}\right)dU_0 = DX.0002\ dU_0$. It remains to determine the value of dU_0, and from Fig. 14 its relative value will be noted.

In the immediate vicinity of the target the trajectory and its tangent may be considered identical, and the increment DX may be

taken parallel to the plane of fire. Then $dU_0=\theta-\psi$; and $\tan\theta=\frac{d-d'}{DX}$; and $\tan\psi=\frac{d}{D_0}$ Or, since the tangents of small angles are very nearly equal to the values of the angles $-dU_0=\frac{d-d'}{dx}-\frac{d}{D_0}$, which is, in turn, obtained from the abaque. The lateral deviation will then be expressed by $DX\left(\frac{d-d'}{dX}-\frac{d}{D_0}\right)+DX\ (.0002)\ dU_0$.

In summary, it might be pointed out that an adjustment requires two distinct divisions in the method of operation. First, the deviations (*da* and *de*) of the actual bursts from the point of fictitious burst are obtained; and, second, the height of the actual burst is obtained, and this height is used to determine the prolongation of the trajectory in relationship to the target for the final deviations. The total horizontal deviation is expressed by E, and the total lateral deviation by *e*. By a combination therefore of the two sets of deviations the following is the result—

$$E=da+(Dx-Q)$$
$$e=de-DX\left(\frac{\pi}{20,000}\right)dU_0.$$

From the above it will be noted that *da* and *de* are obtained from the graphic chart, Fig. 9. Q is obtained from the abaque, Plate I; and so, also, dU_0. (DX—Q) is scaled, from the diagonal line to the curve, in Fig. 12.

OPERATION.

The method of adjustment is carried out in very precise manner, each step in the operation being definitely defined, so that the procedure may almost be said "to be performed by the numbers." The French pamphlets prescribe that the following data shall be transmitted by the Battery Commander to the Telemetric Section:

(1) The time of opening fire;
(2) The nature of the adjustment required;
(3) The caliber and model of the gun, type of shell, powder charge and fuse;
(4) The coordinates and altitude of the battery and target;
(5) The range and gisement from battery to target;
(6) Any miscellaneous information which will assist in the adjustment.

This information is all noted on special printed forms, prepared for the purpose, and as soon as possible the Battery Commander is informed of the height (H'_{Ω}) at which it is desired the bursts shall occur, and the range to the point of adjustment. This enables the Battery Commander to compute the time of flight to Ω, and from special graphs he obtains the proper number for fuse setting.

The Telemetric Section then proceeds with the preparation for the initial data for the adjustment, a plotter and computer working in conjunction at adjacent tables, and the following is the prescribed order of procedure:

PLOTTER.	COMPUTER.
Plots battery and target on plotting board; checks value of U_0, and determines, by scale, value of $0.08\ D_0^2$	Fills in information sheet, constructs horizontal line on prolongation abaque for proper angle of fall, in preparation for determination of value DX.
Plots Ω, approximately, and scales Q, σ_1, σ_2, $0.006A_1^2$ and $0.006A_2^2$, and measures by protractor θ_1, θ_2, and p.	Determines values dU_0 $\left(\frac{\pi}{20,000}\right)$ either from tables or from abaque.
Plots line for value of H′, and determines value of H'_{Ω}	Determines value of Q from approximate value of H'_{Ω} submitted by Plotter, and checks approximate value
Plots (DX—Q) curve from values submitted by Computer, and submits chart to Computer.	

It will be seen therefore that the system requires plotters and computers quite familiar with the elementary principles of trigonometry, but that each step in the calculations is checked by an independent method. Printed forms are employed for the calculations, and on the following sheet an example has been worked out.

COMPUTATION OF TELEMETRIC ELEMENTS.

Section. . . . .

Base. . . . .

Date . . . .

Time . . . .

Battery . . . .

Target:

$0.08\,D_0^2 = +\ 1.78$
$Z_0 = +337.00$
$-(Z_0 + 0.08D_0^2) = -338.78$
$Z = +367.00$
$K' = +\ 28.22$

$C_2 = +341.$
$0.066A_2^2 = +\ 3.79$
$C_2 + 0.066A_2^2 = +344.79$
$-(Z_0 + 0.08D_0^2) = -338.78$
$J_2 = +\ 6.01$

$C_1 = +358.$
$0.066A_1^2 = +\ 2.05$
$C_1 + 0.066A_1^2 = +360.05$
$-(Z_0 + 0.08D_0^2) = -338.78$
$J_1 = +\ 21.27$

$H_\Omega = 118.$

$Q = 250$

$x = +45687.$
$a - x = -\ 120.0$
$a = +45567.0$
$-A_2 = +41935.0$
$a - A_2 = +\ 3632.0$

$y = +34275.$
$\beta - y = -\ 236.3$
$\beta = +34038.7$
$-b_2 = +27385.$
$\beta - b_2 = +\ 6653.7$

$a = +45567.0$
$-a_1 = +45060.0$
$a - a_1 = 507.0$

$\beta = +34038.7$
$-b_2 = +28480.0$
$\beta - b_2 = 5558.7$

$\log\ (a - A_2) = 3.50015$
$\log\ (\beta - b_2) = 3.82306$
$\log\ \tan\ W_2 = 9.73709$
$W_2 = 31.81.0 \quad V_2 = 368.19.0$
$-V_0 = 21.45.6$
$\Theta_2 = 53.26.6$
$-P_2\ (\text{net}) = 53.00$
$(M_2 - 100)\ (\text{net}) = -0.26\backslash.6$
$-t_2$ per cent$=$
$M_2 - 100 = -27\backslash.$
$+100.$
$M_2 = 73\backslash.$

$U_0 = 370.10$
$-V_2 = 368.19$
$\varphi_2 = +1.91$
$P_2 = -53$

$U_0 = 370.10$
$-V_1 = 394.21$
$\phi_1 = -24.11$
$P_1 = -27$

$\theta_1 = -27.24.6$
$\theta_2\ -53.26.6$
$p = 26.02$

$\log\ (a - a_1) = 2.70501$
$\log\ (\beta - b_1) = 3.74498$
$\log\ \tan\ W_1 = 8.96003$
$W_1 = 5.79.0 \quad V_1 = 394.21.0$
$-V_0 = 21.45.6$
$\Theta_1 = -27.24.6$
$-P_1\ (\text{net}) = 27$
$(M_1 - 100)\ (\text{net}) = -24\backslash.6$
$-t_1$ per cent$=$
$(M_1 - 100) = -25\backslash.$
$+100$
$M_1 = 75\backslash.$
$-M_2 = 73\backslash.$
$M_1 - M_2 = 2.$

DATA SHEET.

Adjustment No. . . . .

Date . . . .

Determined by Plotter			Determined by Computer		
D_o	4765	Check battery record	$\left(\frac{\pi}{20{,}000}\right) dU_o$	.017	$dU_o=85$
$0.08\ D_o^2$	1.78				$\frac{\pi}{20{,}000}=\frac{.0002}{.017}$
U_o	370.10 369.8	"	K'	$+28.22$	
$0.066A^2_1$	2.05		J_1	21.27	
$0.066A^2_2$	3.79		J_2	6.01	
A_1			h_1	17	Submit to Observer.
A_2			h_2	26	Submit to Observer.
Q	250		Q	265	Check value by Plotter.
σ_1	0.878		α	45567.0	
σ_2	1.195		β	34038.7	
θ_1	-26.9		θ_1	-27.246	Check value by Plotter.
θ_2	-53.0		θ_2	-53.266	Check value by Plotter.
p	26.1		p	26.02	Check value by Plotter.
$H'\Omega$	94.44		P_1	-53	Submit to Observer.
ρ_1	2.917		P_2	-27	Submit to Observer.
			M_1	75	Submit to Observer.
			M_2	73	
			M_1-M_2	$+2$	
			Φ_1	-24.11	
			Φ_2	$+1.91$	

The foregoing, it will be noted, all concerns the initial data, required in advance of observations on actual bursts. It embraces the determinations of all elements required by the observers, in order to direct their instruments to the fictitious point of burst, together with the preparation of the necessary charts on which to plot the angular deviations of bursts, and, finally, to determine the results of the ranging in "longs and shorts, rights and lefts."

The telephone operator in Central tabulate the readings submitted by the T stations, and places this data on the tables where both the plotter and computer can see it. The following is then the order of procedure:

PLOTTER.	COMPUTER.
Plots bursts on chart of equal parallax and equal direction; records the deviations *da* and *de*, and submits results to Computer.	Computes $M_1{}^1—M_2{}^1$.
	Finds value of (DX—Q) from chart, for values of m_1 or m_2 (or both).
	Computes $E=da+(DX—Q)$ $e=de—DX\left(\frac{\pi}{20,000}\right)dU_0$
	Tabulates values of E and *e*, and submits to telephone operator.

(The printed computation sheet is in the following form.)

COMPUTATION SHEET.

Date .... Battery .... Section No. ....

Time .... Target .... Base No. ....

No. of rounds.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
M'_1	76	83	89	40	87	91	110	104	72	85	93	110	92	105	78
M'_2	80	76	82	60	76	61	82	92	85	68	97	72	87	95	72
$M'_1 - M'_2$	—4	+7	+7	—20	+11	+30	+28	+12	—13	+17	—4	+38	+5	+10	+6
m_1	80	110	115	60	96	102	106	99	120	115	103	94	106	122	98
m_2															
da	+18	—10	—7	+142	—17	—66	—44	—10	+43	—36	+29	—76	+3	—6	—7
DX—Q	—70	+45	+68	—138	—15	+10	+27	—1	+88	+68	+18	—20	+27	100	—8
E	—52	+35	+61	—96	—32	—56	—17	—11	131	+32	+47	—96	—30	+94	—15
DX	195	310	328	127	250	275	292	264	353	333	283	245	292	365	257
$DX\left(\frac{\pi}{20,000}\right) dU_0$	3.3	5.3	5.6	2.2	4.2	4.7	5.0	4.5	6.0	5.7	4.8	4.2	5.0	6.2	4.4
de	—7	—4	—10	+17	—5	+11	—12	—24	—16	+5	—29	—3	—18	—25	0
$-DX\left(\frac{\pi}{20,000}\right) dU_0$	—3.3	—5.3	—5.6	—2.2	—4.2	—4.7	—5.0	—4.5	—6.0	—5.7	—4.8	—4.2	—5.0	—6.2	—4.4
e	—10.3	—9.3	—15.6	+14.8	—9.2	+6.3	-17.0	—28.5	—22.0	—0.7	—33.8	—7.2	—23.0	—31.2	—4.4

COMMENT.

It is obvious that one of the principal weaknesses in the Telemetric System is the lack of check in the employment of only two observation posts, whereas with the use of three or more posts information would be obtained showing the error involved in observations. There would seem no good reason, however, why three posts could not be arranged as a unit. The method of reading the horizontal angles would then have to be changed, so that the observations from the middle post could be used for the two bases. At present the only means of obtaining a check is to employ two separate bases for an adjustment, which necessitates the employment of two sets of computers and plotters.

In the matter of drift and wind correction, quite a good deal of time is consumed in determining these deviations, and, as will be noted in the example given, the amount of this correction is almost negligible. It would therefore seem proper to discontinue this particular method in obtaining these corrections, and, instead to formulate tabulated values for drift and wind deviations.

The observation instruments are, from the American Engineer's point of view, decidedly unsatisfactory, and, undoubtedly, range practice will develop important suggestions for changes. Along this line, it would be very desirable if an instrument could be designed suitable for flash observations, and, perhaps with additional appliances, also sufficiently accurate for observations on high bursts. The Flash Sections in the A. E. F. were, however, provided with two distinct types of instruments, which were employed for the particular mission desired—"spotting" enemy's guns or ranging on high bursts for friendly artillery.

Although the Telemtric System possesses the excellent point of merit of prescribing a definite routine for each step in the operation, many of these steps are, nevertheles, quite involved. In particular, the construction of the charts shown in Figs. 9 and 12, required for each adjustment, are quite involved and require considerable time for preparation. Shorter method for determining the same data can undoubtedly be developed when the system is operated with a view of improving method rather than arriving at actual results.

The main point, however to be considered in the Telemetric System is that its operation requires an highly trained personnel, fully conversant with the trigonometric theory involved, and that it can not be employed, on short notice, as an alternative for any other method of ranging.

BRIDGING THE RHINE WITH GERMAN PONTON EQUIPAGE.

By

Col. S. C. Godfrey,
Engineers, U. S. Army.

The following notes describe a ponton bridge across the Rhine, built by the 2nd U. S. Engineers on May 25, 1919.

Some months previously, a ponton school had been established on the Rhine by the Chief Engineer, III Corps. There was available for this purpose at Honningen a considerable amount of German ponton equipage which was collected in the occupied area and which, according to the terms of the armistice, became the property of the United States. This site was selected from tactical considerations.

Companies of the 308th Engineers, III Corps Engineer Troops, first attended the school successively for periods of instruction lasting 10 days. After several companies had received this training, a combined detachment of 400 men, working from both banks, constructed a bridge entirely across the river—the first Rhine crossing ever built by American troops.

In order to give the regular engineer regiments an opportunity for this training, the Ponton School was turned over to the 2nd Engineers on May 12th. A detachment of 200 men from "D" and "F" Companies received a 10-days' training. On May 21, another 200 men from the other companies were sent to the school for a short 3 days' period of training. Arrangements had been made, on the morning of May 25, to suspend all river traffic for the period of two hours in order that a bridge might be completed all the way across the Rhine. Thus the channel portion of the bridge had to be constructed and removed within this time limit.

The Rhine at this point, between Honningen and Niederbreisig, is about 1,440 feet wide. It is a swift flowing stream; the fall in this vicinity is 15 inches per mile, and the current in mid-channel at this time was about 4½ miles an hour; the maximum depth at

this point is about 25 feet. The bottom of the channel section is scoured smooth and is not very good holding ground for anchorages. According to the German Military Notes, this site is not recommended as a favorable location for a ponton bridge; and the feasibility of such a crossing was first demonstrated by the 308th Engineers.

The German equipment can best be described by reference to the following table, and by the photograph and sketches which illustrate the chief points of difference between this and our own equipage.

Comparison of American and German Heavy Ponton Equipment.

Name of Part.	German. Dimensions, approximate.	American.
Ponton, size	26′×5′×2′10″	31′×5′8″×2′7″.
weight	1,100 pounds	1,600 pounds.
displacement	19,000 pounds	21,000 pounds.
safe net buoyancy	16,000 pounds	18,000 pounds.
Balks (long), size	20′×6″×4″	27′×5″×5″.
Balk (trestle), size	15′×6″×4″	21′8″×5″×5″.
Chess, size	12′6″×10″×1½″	13′×12″×1½″.
Lashings, size	½″×14′	½″×18′.
Anchor cable, size	1¼″×150′	1¼″×180′.
Anchors, weight	125, 275 and 500 pounds.	150 pounds.

The steel boats, being considerably lighter than the U. S. wooden boats, are more easily handled, both in and out of the water. The bow end has a raised gunwale. Each wagon carries eight balk and twenty chess underneath the overturned boat—a bay complete in itself.

The balks have a rectangular cross-section, the greater strength of which is a point in their favor. The ends are provided with conical pins, which engage sockets riveted to the gunwales of the boats. (See Fig. 1.)

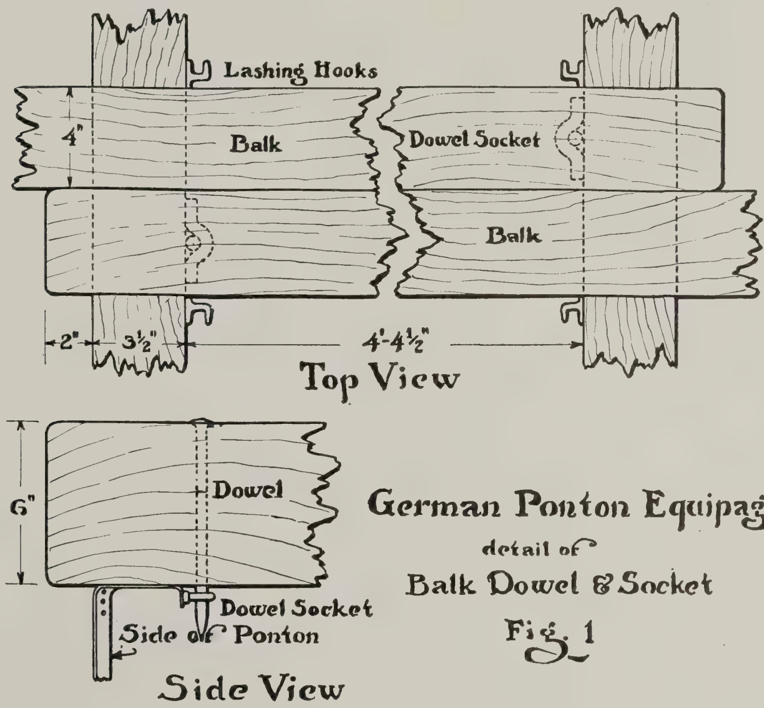
The trestle has vertical legs. The cap is securely clamped to the legs, with a device for adjusting its height which operates simply and effectively. (See Fig. 2.) This trestle is much superior to the Birago.

The following notes on the organization of the German Ponton Train are taken from a British publication:[1]

[1]Handbook of the German Army in War, April, 1918; issued by the British General Staff.

Bridging trains. Bridging trains were formerly attached to divisions, corps and armies, but, at the end of 1916, they were withdrawn from lower formations and reorganized as G. H. Q. troops, being allotted to Armies as required. As the details of the new organization are not available, the old composition of bridging trains is described below.

(*a*) *A Divisional Bridging Train* (*Divisions-Brucken-Train*) used to form part of every division. The bridging train was attached to the divisional pioneers, but the personnel and horses were all drawn from the train.



German Ponton Equipage
detail of
Balk Dowel & Socket
Fig. 1

The bridging train is organized in two sections and a reserve section.

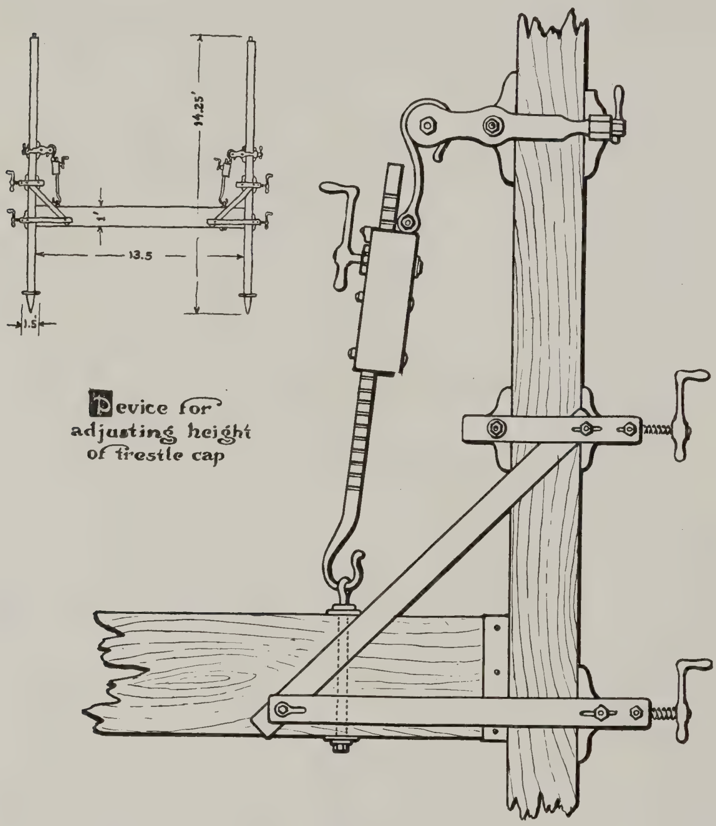
The establishment of a divisional bridging train is—

2 officers,
59 other ranks,
98 horses,
21 vehicles.

The bridging material is carried on—

12 ponton wagons (each carrying a half-ponton),
2 trestle wagons,
1 shore transom wagon.

These wagons are 4-horsed.



German Ponton Equipage
Fig. 2

The six pontons of a divisional bridging train are of galvanized steel and are bipartite. The bow pieces have a raised bow to give extra safety in rough water. Both bow and stern pieces are 14 feet 6 inches long, 4 feet 7 inches wide, and 2 feet 9½ inches deep internally. The bow piece weighs 661 pounds and the stern piece 683 pounds. The freeboard (amidships) of the bipartite ponton

varies from 31 inches (unloaded) to 3½ inches (with a load of 7¾ tons).

(*b*) *A Corps Bridging Train* (*Korps-Brucken-Train*) was formerly attached to the headquarters of every Corps. It is organized in two half-columns and a reserve section, and has a pioneer detachment of 2 officers and 64 other ranks.

The establishment of a Corps bridging train is—

Pioneers—

2 officers,
54 other ranks;

Train—

4 officers,
138 other ranks;
1 medical officer, 1 veterinary, 1 paymaster;
239 horses;
39 vehicles.

The bridging material is carried on—

26 ponton wagons (each carrying 1 whole ponton),
2 trestle wagons.

These wagons are 6-horsed, but the establishment of horses is believed to have been reduced recently.

The 26 pontons carried by a corps bridging train are galvanized steel whole pontons, 26¼ feet long, 4 feet 11 inches wide, and 2 feet 9½ inches deep internally, weighing about 1,102 pounds. The bow and stern are similar to those of the bipartite ponton, and their buoyancy is practically the same.

(*c*) *Bridging Capacity.* Normal bridge is designed to take all weights up to 3.14 tons. For 21 cm. mortars, long 15 cm. guns and all vehicles weighing between 3.14 and 4.92 tons, normal bridge is strengthened by doubling the balks under the wheel tracks. For the army mechanical transport trains (greatest weight on each back wheel of tractor, 3¼ tons), the bridge must be constructed with twice the number of pontons required for normal bridge, the number of balks is increased from five to nine and the chesses are doubled.

This type of heavy bridge may be used by fully loaded mechanical transport trains across rivers with a velocity not exceeding 5.1 miles an hour.

The bridging capacity of the divisional and corps bridging trains is as follows:

Nature of bridging train.	Bridge.			Time of construction.	Number of pioneer companies required
	Light.	Normal.	Heavy.		
	Yards.	*Yards.*	*Yards.*	*Hours.*	
1 Divisional bridging train	65.6	38.3	21.9	½-1	⅓-1
2 Divisional bridging trains......	131.2	76.6	43.7	2	⅔-1
1 Corps bridging train	185.9	142.2	82	3	1-2
1 Corps and 2 Div. bridging trains.	328	218.7	131.2	5	2
1 Corps and 3 Div. bridging trains.	393.7	251.5	153.1	5	2
1 Corps and 4 Div. bridging trains.	459.3	295.3	175	6	2-3

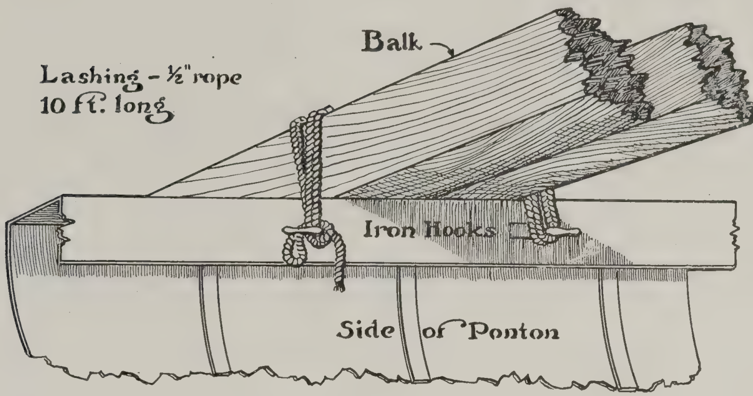
German methods of laying bridges are very similar to ours, except for the lashings and certain other details which are dependent on the design of the members.

Thus, the balk pins are inserted in the sockets before "shoving off," and no preliminary lashing turns about the balk are necessary. The boat crew remains in the boat until it is shoved off, and then comes ashore, while both ranks of lashers are engaged simultaneously on the next to the last boat. The balk lashing itself is very simple and is rapidly made. (See Fig. 3.) No frapping turns are taken. It is not as good a lashing as ours, and must require considerable attention under service conditions. The side-rail lashing is made from a single turn of heavy ¾-inch rope (see Fig. 4); it is more readily made than ours, and is at least equally satisfactory.

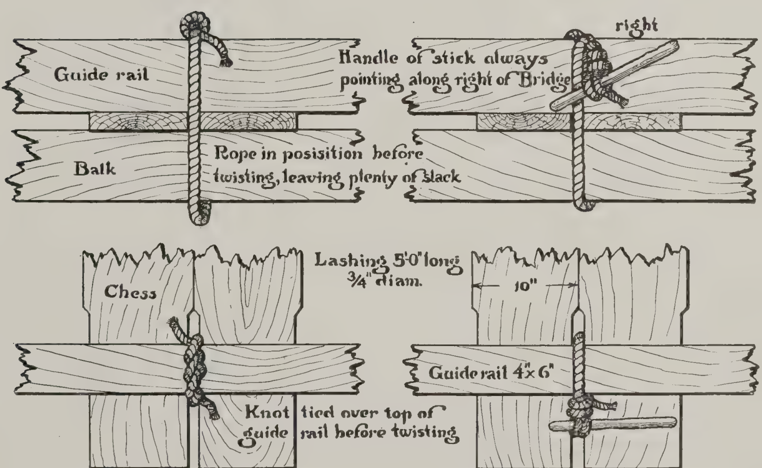
The organization for the construction of the bridge differed somewhat for the two sides, since the channel is nearer the left bank. On the quieter side, where it was proposed to build somewhat more than half the bridge, details were provided for 10 boat crews (one of which was also an abutment squad) composed of the best trained men; three sets each of balk carriers, chess carriers and side-rail carriers; 10 balk lashers and 2 chess layers, the latter trained to interchange with the lashers for relief; 4 side-rail lashers; 5 cable-men; and 6 trestle-men.

An upstream anchor was provided for every boat, and a downstream anchor with two lines for every six boats. The anchors were cast about 200 feet above the bridge. One trestle was used on this side of the river.

In order to cut down the long carriage of materials, it was planned to construct simultaneously with the bridge a 4-boat raft



German Ponton Equipage
Detail of Balk Lashing
Fig. 3



German Ponton Equipage
Side Rail Lashing
Fig. 4

loaded with material for 20 bays, and to tie this raft to the bridgehead upon the completion of the first 30 bays. This raft detail of 6 men was aided at first by boat crews and carriers not otherwise engaged at the start.

Arrangements on the other side of the river were very similar, except for the additional provision of two 500-pound upstream anchors with longer lines in the channel section. On account of the steeper bank, two trestles were necessary on this side. No raft was used, the materials being all carried from the bank.

Two gasoline launches were available, and these were assigned to the officers in charge of the boat details. During the preliminary practice, there had been much difficulty in spotting the anchors correctly; the tendency was to drop them too close to the banks, thus adding to the difficulties of the boat crews in reaching the bridgehead successfully. The swift current necessitated most careful handling of the boats. A ponton, once jammed across the bows of the other boats in position in the bridge, could be removed only by the help of the launch. A boat which found itself too far out caused less difficulty, as it could wait in position until another ponton had filled the gap. The boat crews that cast the downstream anchors had to work back and forth on a line connected with the bridge, as they could not make any headway, unaided, upstream against the swift current.

The actual construction of the bridge went very smoothly; no delays of any consequence occurred. One ponton got away below the bridge, but was caught and pulled back by one of the launches. One anchor was lost, due to a rotten cable. The raft was completed, was worked out below the bridge to its place, and was utilized successfully to complete the longer reach of the bridge. The two ends met quite accurately after the completion of 49 bays on the raft side and 46 bays on the other. The bridge had a slight upstream bow. The average time for a bay was a minute and a quarter—better than had ever been done in practice. The last side-rail lashing was completed in 58½ minutes after the commencement of the bridge.[1] Shortly afterwards "B" Battery of

[1]Note: Subsequent to this fine performance of the 2nd Engineers, the 1st Engineers at Honningen, about 15 km. below Neuweid, constructed a similar bridge in the remarkable time of 41 m. 8.2 sec. At this point the river is 1,450 feet wide, depth of channel 25 feet, current 3 to 4 miles per hour. The number of pontons used was 93, and the number of men engaged was 400.—ED.

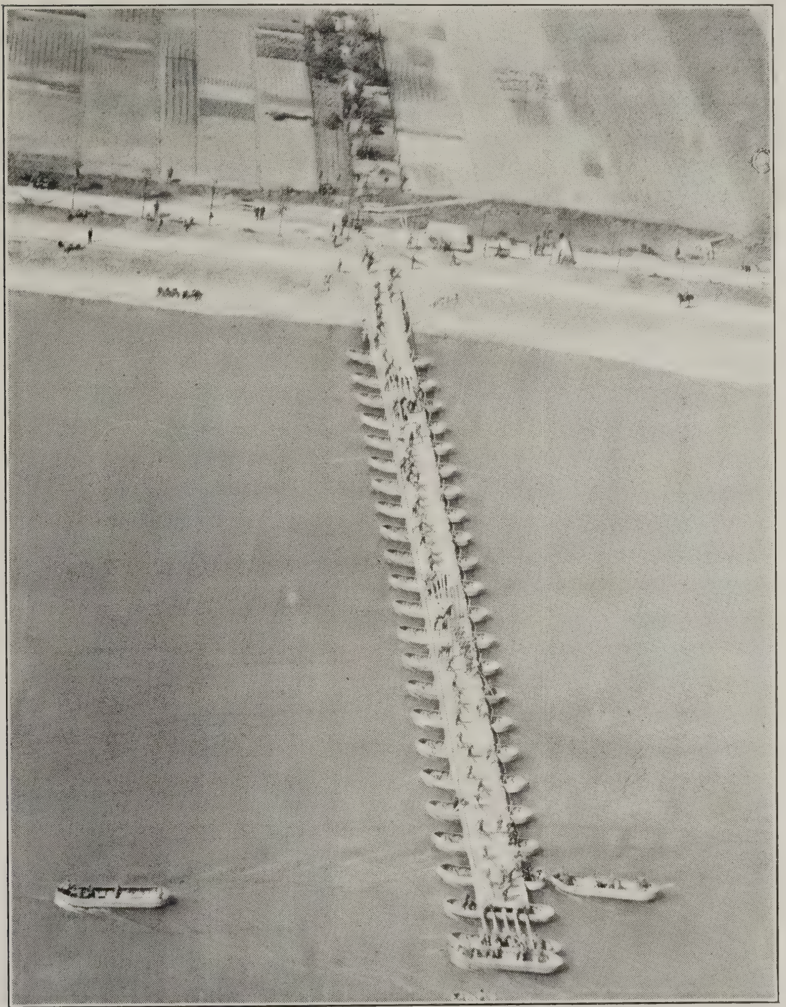


Fig. 5. Photograph taken from the air at a height of 200 meters and showing west end of the bridge under construction.

the 12th Field Artillery crossed the bridge. It is stated on good authority that the best time ever made in bridging the Rhine by skilled German pioneers is 1½ hours.

As a whole, the German ponton equipage is of excellent design and fabrication. Our troops found it easy to handle, and readily acquired the requisite familiarity. This regiment has had no opportunity to experiment with the loaded wagons on the road, nor with the methods of repairing damaged boats in the field. The contemplated transfer of some of this equipment to the United States will afford a chance for comparative tests, and will undoubtedly reopen the old discussion as to the relative merits of the steel and the wooden ponton.

NOTES ON ORGANIZATION OF GERMAN ENGINEERS.

I. THE DIVISION.

The Division normally had assigned to it two field companies of about 250 pioneers each. During operations, these companies would usually be attached, one to each of the two infantry regiments in the front line. (Of the three infantry regiments in a division, one was usually in reserve.) For special purposes, other companies from the army engineer troops were often attached to divisions. Thus, for a campaign involving river crossings, the leading divisions might each have operating with them as many as five pioneer companies, together with an equal number of companies of labor troops (see below), or a total of about 2,500 men.

The major commanding the battalion of pioneers was also the Division Engineer. At first simply a commanding officer of troops, he was later recognized as a member of the Commanding General's staff, in a position analogous to the Chief Artillery Officer. As such, he was in charge of lines of communication and supply, and field fortifications, and was empowered to issue orders in the General's name. He prepared the plan of engineer operations, based on the Army Engineer's plan. He reported to the Chief of Staff (a General Staff Major) or to the Commanding General direct. It has been urged that the Division Engineer should be a staff officer pure and simple, and be distinct from the Engineer battalion commander.

II. THE CORPS.

No Engineer troops were normally assigned to the Corps. Exceptions arose when a Corps was operating independently, or was charged with some important line of communication, in which case a regiment (six companies) might be attached. The Corps Engineer, a Major or Captain, was an *advisor* on the staff of the Commanding General. The Corps transmitted the operation orders of the Army to the Divisions without sensible modification or independent orders. (A Corps, two or three Divisions, 25,000 to 37,500 men, at full strength was hardly larger than our Division. ''The Army Corps, of two Divisions, which, in peace, formed the unit of

higher command, has not proved a suitable formation under war conditions. The unit of strategic manœuvre has become the Division, and Divisions have in practically all cases become entirely independent of their original Corps grouping. Corps' staffs normally remain semi-permanently in a sector after the divisions composing the Corps have been transferred elsewhere."—*Quotation from British staff publication.*)

III. THE ARMY.

The Army had at its disposal two or three regiments of Pioneers, sometimes more (regiments varied in strength, but most commonly contained two three-company battalions). The Chief Engineer was a General Officer, with his own staff, which included an officer in charge of roads, another of railroads, another of Engineer munitions (such as grenades and explosives). He prepared the plan of Engineer operations dealing with roads, Engineer supplies, distribution of Engineer troops; and dominated Engineer activities throughout the Army area, which extended back perhaps 20 kilometers from the front line.

The Army had available a pool of labor troops, unarmed, comprised chiefly of men incapacitated for combat service. These were distributed according to the needs of the particular situation. A common allotment was to provide one labor company to supplement each pioneer company engaged.

It is thus seen that the assignment of Engineer and labor troops was somewhat more flexible than in our Service. Other resources in the way of troops existed in the Army groups and General Headquarters farther back.

The special railroad troops were also of a non-combatant character. This served well enough for S. O. S. purposes, but not for the exacting demands of the front. These railroad troops were not numerous enough and lacked the necessary punch to make good in the vital need of extending the R. R. lines during the major offensives.

IV. THE S. O. S.

The Commanding General of the zone of the étape was at G. H. Q., evidently in closer touch with the armies than under our organization. Nevertheless, the officers I have talked with were keenly conscious of shortcomings in their service of supplies, and felt that this function had shown up less favorably than their com-

batant forces. They were handicapped by having to employ trucks with iron tires, which involved a heavy wear and tear on the roads. Railroads could not be pushed forward fast enough to accompany their advances. They lacked a supply of heavy portable R. R. bridges. The bringing up of ammunition for their lengthy artillery prepartions was a severe strain on their supply service. In many cases, moreover, division commanders were prone to over-run the objectives prescribed for them, in the absence of serious opposition. This involved advances to an extent for which preparations had not been made, and hence often eventual failure.

V. USE OF ENGINEERS AS INFANTRY.

Regulations prohibited the use of Pioneers as Infantry, except in cases of grave emergency. Unwarranted employment sometimes occurred, as with us, where the Engineers were not properly represented at Headquarters, or where some infantry commander exceeded his authority in directing the Engineer troops attached to his unit. Their use for combat was more common on the eastern front, on account of the greater extent of the territory over which each unit was operating.

In this connection, it is interesting to note that the infamous saw-toothed bayonet was the bayonet issued the Pioneers—so fashioned in order to permit its use as a wood saw. As the Germans came to feel that capture with this weapon in their posssesion invited sudden death from their Allied captors, these unpopular blades were gradually exchanged for the infantry smooth-edged type.

VI. CONCLUSIONS.

The German Engineers feel that the war brought an increasing appreciation of the importance of communications and the vital need for Engineer troops.

The Division, it is claimed, should have *three,* rather than *two,* Pioneer companies permanently assigned to it—which gives practically the same proportion of Engineers as our present organization calls for.

Another lesson of the war, these Germans state, is that a good railroad in the general direction of the advance of an army is more than ever a *sine qua non* for a successful offensive. Roads alone cannot suffice for the supply service of such operations.

NOTE. These observations result from an authorized interview of several German Engineer officers, by Colonel S. C. Godfrey, C. E.—EDITOR.

THE ENGINEER SCHOOL AT CAMP A. A. HUMPHREYS, VA.

By

Capts. E. F. Gaebler and W. E. Duckering,

Engineers, U. S. Army.

The present Engineer School at Camp Humphreys owes its existence to the fact that, in 1918, due to the pressing need for engineer officers, a number of cadets of the classes of 1919 and 1920, of the U. S. Military Academy, were commissioned as engineer officers without having received the fundamental engineering education required by their prospective duties. The high standard for entrance in the Corps of Engineers has been carefully maintained for a great many years. It was necessary, therefore, as soon as the Armistice was signed, to take steps to enable these officers to complete the training which the emergency had denied them. General Black, the Chief of Engineers, had given the matter a great deal of earnest thought and consideration, and had reached the conclusion that the time was ripe for taking a definite step toward the improvement of methods of engineering education. The necessity for taking this step was all the more apparent because it was not feasible to send the officers to West Point to complete their training, owing to the confusion which must arise with the introduction of so many special students and special courses. Neither was it advisable to remove these men entirely from the sphere of military training, after only a partial course at West Point, and send them to a technical school for the purpose of completing regular engineering courses. On the other hand, a close study of the methods of education employed in engineering schools, and the results of the examination of civilian candidates for entrance to the Corps of Engineers, convinced the Chief of Engineers that it was possible to break away from traditional methods and establish an Army Engineer School which would more nearly supply the particular kind of training that an engineer officer requires, and at the same time employ such of the progressive educational methods as he believed likely to prove successful in preparing engineers.

To fully appreciate the school, therefore let us briefly consider the needs of the army engineer. In time of war, the digging of trenches, the building of highways, the construction and maintenance of railways, and the improvement of docks and wharves, all require a knowledge of civil engineering. The use of explosives in demolition work, and the principles of gas warfare, require more or less of the training of a chemical engineer. In the early part of the war a knowledge of mining was necessary in the driving of tunnels under ''no man's'' land, and in the construction of bomb proofs and dugouts. The officer also had to know the principles of mechanical and electrical engineering, because of the extensive use of electricity and machinery. Hence, we see that in war time the army engineer must be an ''all around'' engineer, as General Black expresses it, and not necessarily a specialist.

In time of peace, Congress has entrusted to the Corps of Engineers certain duties in connection with the enforcement of navigation laws, and the care of river and harbor improvement projects, which require a knowledge of hydraulic engineering; and the building of fortifications, and seacoast defenses, which combine the principles of military and civil engineering. In addition to this, there have been special types of work in the last few years which show that the army officer must be prepared for any emergency or any class of work, such as the construction of the Panama Canal, the cleaning up of Havana and the raising of the *Maine*. The widest training only will suffice in preparation for the work of peace times, though if the officer is also a specialist it is so much the better.

METHODS OF ENGINEERING EDUCATION.

With this general outline of requirements of the army officer in mind, let us next examine what seems to be the general requirements for an engineering education. The curriculum of instruction in the average engineer school consists of courses in pure mathematics and the general theory of science, to be applied from two to three years later, in engineering studies. For years this method had been followed with a certain amount of success. But there is an inherent fault in this system that seriously handicaps its efficiency. The student is not able to develop sufficient interest in these purely abstract studies to lead him to attempt to master them thoroughly enough to apply them two years later. Furthermore, even if the student actully sees fully the need of all the preliminary train-

ing he receives, it is impossible for him to gain the necessary working knowledge of the principles he studies without concrete examples of their application. The present method therefore involves two serious faults. It fails to orient the student properly at the start, and it does not give him that intimate association between the theory and its application that he must have to gain a practical knowledge of the tools that he is later to employ. It also fails to supply the student with a satisfactory motive. The highest incentive to any man is the firm conviction that the work in which he is engaged is a work really worth while. The best morale can be maintained among students only when they see that what they are studying is really fitting them for their life work, and that this work has a deserving place among the activities of the human race.

The methods in use at the Engineer School aim at the correction of these faults and are intended to develop independent thinking on the part of the student, by inductive rather than deductive methods of attacking problems. With the usual ''text-book'' method, it is inevitable that either the teacher, or the author of the text-book, does most of the thinking for the student. The student continually accepts the finished product of the mental efforts of others, and is brought to the conclusion so rapidly by the teacher that he does not have time to appreciate the processes of reasoning employed in reaching the conclusion. This tends toward the development of a ''handbook Engineer'' who merely depends upon formulæ. Thus the prime qualities of a good engineer, the ability to think for himself, to make a keen analysis of new situations, and to arrive at logical conclusions based on thoughtful investigation, may be lost. The Engineer School endeavors to avoid these bad effects by presenting interesting engineering problems to the student in such a way that he is impelled to think them out for himself, and seeks the methods of solution for his own satisfaction. The schools in medicine and law, developed from a desire of professional men to perpetuate the results of their experience, but engineering courses developed largely from an attempt of the followers of pure science to furnish technically trained men to our industries. In the law school the student is presented with concrete cases, and from the analysis of them he learns the general principles of law. Similarly, in the school of medicine, the student learns anatomy in the laboratory by the dissection of a cadaver. The Engineer School at Camp Humphreys endeavors to teach engineering by these same methods, wherever feasible. It teaches the investigation of concrete

problems, and encourages the student to do his own thinking as far as possible.

Throughout the engineering world there is a general lack of appreciation of the close coordination between engineering and the so called "humanistic" studies. Too often our schools turn out "human calculating machines," who are never anything more than "hired experts." But "the engineer," says Prof. Aydelotte of Massachusetts Institute of Technology, "must deal with men as well as with machines." The engineer must study, and know how to use, English, for example, so that he can think and express himself in terms that other men will understand. He should know something of social philosophy, and the principles of economics. To secure this result, it is essential that the student be constantly imbued with the idea that the subjects he studies are not ends in themselves, but means to an end.

The subject-matter of any course is chosen with the view of bringing the fundamental principles before the student in a real engineering manner. By continually confronting the student as far as possible, with typical engineering situations, he eventually learns to discern in them fundamental principles that he recognizes as tools with which he can work, and he gradually learns to seek principles on his own initiative. The larger problems of the engineering world are broken up, in the class room into smaller ones so that the student may not be swamped by a multiplicity of detail, yet he constantly lives in an engineering atmosphere, and is also kept in touch as far as possible with the latest developments of engineering.

WAR MATÉRIEL FOR USE ON NATIONAL HIGHWAYS.

The Post Office Appropriation Act, for the current fiscal year, authorized the Secretary of War, in his discretion, to transfer to the Secretary of Agriculture all available war matériel, equipment and supplies not needed by the War Department but suitable for use in the improvement of highways. This matériel was to be distributed among the highway departments of the various states to be used on roads constructed by Federal aid. The Department of Agriculture has made several canvasses to determine requirements and has determined upon a tentative distribution of the several classes of supplies and equipment, which include machine tools, engineering and construction equipment, building material, truck and motor equipment, general supplies, explosives, horses and mules, tractors, trailers and caterpillars. Over 20,000 motor trucks and 1,500 automobiles have been allotted to the 48 states and the forestry and public road services of the National government. Shipping directions have been given for various lots of construction materials and camp, mess and kitchen equipment, relatively small in the aggregate as compared with requirements. The Chief of the Bureau of Public Roads states that during the war highway construction moved slowly on account of the shortage in labor and the control of building material for war purposes, and that only recently have the several state highway departments been able to begin work on their respective new programs, which can not be compared in importance and size with the work which was done during any preceding year. He is of the opinion that the state requirements for equipment and supplies will greatly exceed the quantities which can be made available by the War Department.

NOTES ON THE INLAND WATERWAYS OF FRANCE.

By

Lt. Col. L. E. Lyon,
T. C.; M. Am. Soc. C. E.

An inspection of a map of France showing its improved rivers and canals shows that most of the navigable waterways of that country lie in the north, center and east; that is, largely in the industrial sections of France. The western and southern parts of France are not altogether devoid of navigable waterways, but they are there much less numerous and do not possess physical connection with the waterways of other parts of the country. A barge starting from Marseille or Bordeaux would be unable to reach the north or east of France by inland water routes. The waterways in the northern, eastern and central parts of the country have physical connection with each other and with the canals of Belgium. The depth and other channel dimensions of the waterways in the north, east and center are also greater than those in the south and west.

Very few of the large seaports of France have continuous waterway connection with distant interior points. Le Havre and Rouen, both on the Seine, the former at its mouth and the latter seventy-five miles upstream, are the two most important ports having such connection. Dunkirk, Calais, Gravelines and St. Valery also have such connection. If one follows the coast line south of Le Havre down to the Spanish border, no port having this connection is encountered. The same is true of the entire French coast along the Mediterranean Sea.

French waterway officials classify the navigable rivers and canals of the country into two categories based on channel dimensions, and known as the 1st and 2nd categories. The 1st category includes all rivers and canals having a minimum navigable depth of 6.56 feet, and the locks upon which have a usable length of 126.28 feet and a usable width of 17.06 feet. All rivers and canals having less channel depth and locks of smaller dimensions fall in the 2nd category. The minimum dimensions of the 1st category waterways are the dimensions to which many rivers have been im-

proved and canals built and of the operating appurtenances of many of the latter. Certain improved rivers, like the Seine, Marne and Yonne have greater channel depth and width and larger and longer locks, but these are exceptions. The largest 1st category canals have channel depths of from 6.56 feet to 7.22 feet and locks with 126.28 feet usable length and 17.06 feet to 19.68 feet of usable width.

Boats built for 2nd category waterways can navigate upon 1st category waterways if physical connection exists between them, but boats built to the maximum dimensions of 1st category waterways can not be accommodated upon 2nd category waterways.

Certain waterways overcome great differences in elevation, while others, as in northern France, lie in quite flat country. Great differences in elevation, and the consequent necessity of numerous locks, do not seem to have discouraged the French engineers in projecting and building canals. On the Canal de Bourgogne between Laroche and Saint-Jean-de-Losne, in a distance of 150 miles there are 189 locks, or a lock on an average upon every 0.79 mile. On the Canal de la Marne au Rhin in a distance of 129 miles, between Vitry-le-Francois and the former German frontier, there are 113 locks, or the average distance between locks is only 1.14 miles. On the Canal de la Marne à la Saône, between Vitry-le-Francois and Heuilley-sur-Saône, a distance of 139 miles, there is a total of 113 locks with an average distance of 1.23 miles between locks. In northwestern and northern France, locks are less numerous upon the canals. Upon the Aire Canal, between Bouvin and Aire, in a distance of 25 miles, there is only one lock; on the Canal lateral à l'Aisne, in a distance of 32 miles between Vieux-lès-Asfeld and Celles there are 8 locks, or the average distance between locks is 4.0 miles; on the Canal de Calais, between le West and Calais, a distance of 19 miles, there is only 1 lock. As a rule, locks are numerous upon canals in France as viewed by the American engineer and as compared with canals in the United States.

The improved rivers in France are nearly all improved by systems of locks and movable dams where the original bed of the river is retained for the channel. Dredging and training works have not been used to the extent that they have been in the United States. Among the principal rivers of the 1st category canalized by locks and dams are the following: the Seine, the Marne (between Epernay and Charenton), the Yonne (between Auxerre and Monterau),

the Saône (between Corre and Lyon), the Morelle (between Frouard and the former German frontier) and the Aisne (between Celles and its mouth where it enters the Oise).

Lateral canals, or canals built parallel to rivers to provide for navigation in a channel constructed outside of the river bed, where the slope of the river is too steep to permit navigation or where for other reasons the bed of the river is unsuited for navigation, are common in France. The principal lateral canals are the following: Of the 1st category, Canal lateral à la Marne between Vitry-le-Francois and Dizy, the Canal lateral à la Loire between Digion and La Cognardière, Canal lateral à l'Oise between Chauny and Janville and the Canal lateral à l'Aisne between Vieux-lès-Asfeld and Celles. In the 2nd category, there is the Canal lateral à la Garonne between Toulouse and Castets.

The canals of France generally give an impression of careful design and good workmanship and present a well-kept appearance. A towpath is found on one side and sometimes on both sides. Rows of large trees planted at regular intervals border both sides of the canals, a short distance from the water's edge, or on the land side of the towpath. Where curves exist these are carefully laid out and the canal built true to line. There is a growth of grass on the banks, but this is short and free from rank growth of weeds. At sharp curves, at approaches to bridges, at city and town fronts, carefully constructed masonry walls border the canals. The bridges over canals have usually a headroom which is only sufficient to allow the passage of canal boats floating light. The bridges are almost invariably fixed, the movable bridge being a rarity.

The canal locks are simple in construction, built of masonry; and the more modern ones of concrete. Except in unusual instances, lock gates are operated by hand, as their small dimensions and moderate weight permit of this mode of operation. The valves for the admission and discharge of water at the locks are also almost always operated by hand. A house for the lock-keeper is provided at each lock. Upon the more important canalized rivers, the locks are larger than upon the canals, but upon the smaller ones they do not differ from the canal locks. Where movable dams exist, a larger operating personnel is provided, quarters for attendants are more plentiful and the necessary shops for repairs are to be found.

As a rule, navigation upon the inland waterways of France is

not carried on at night. Single crews are the rule upon barges, tugs and other craft. Only one lock-keeper is on duty at the majority of locks. The larger and busier locks upon the principal rivers are provided with assistants to the lockman. Regulations concerning signal lights on craft after sunset are in force and bridges and locks are indicated at night by established lights. No lights are provided along towpaths. Tips to lock assistants handling lines for boatmen is a common practice and these tips are expected on certain rivers. Whenever required, a statement as to the amount and kind of cargo carried must be submitted by the master of any boat. The information furnished is used for compiling commercial data and statistics regarding the use of the canals. Barges carrying explosives or highly inflamable cargo are required to comply with rigid regulations governing the transportation of cargo of this character.

Nearly all the traffic on the waterways of France is on barges. The types of barges used carry their cargo in the hold. Barges carrying deck loads are almost unknown on the inland waterways of France. Although self-propelled barges are not uncommon, most boats are not self-propelled. A narrow deck runs along both sides of the barge for its full length and terminates in short decks at both bow and stern. Access to the hold for loading and discharge is given by means of hatch covers constructed in sections. When all hatch covers are removed, the barge is almost entirely open at its top. Rudders are provided on all barges and a long tiller is the most common method of operating the rudder. A type of barge of the maximum dimensions which all 1st category canals and rivers can accommodate has become so common in France as to be almost a standard barge. This barge is known as the ''peniche.'' It passes through a lock of the minimum dimensions of a 1st category waterway with very little clearance as to length, beam and depth when fully loaded. The usual dimensions of the péniche are: 126.28 feet in length, 16.40 feet in beam, and 5.9 feet of draft when loaded so as to carry 300 short tons. It has a cargo space of about 10,590 cubic feet. Like all barges used in France, it carries its load in the hold and is provided with a large rudder. There is a a small deck at the bow and at the stern, and a narrow deck runs along both sides of the barge from bow to stern. A cabin, usually placed in the center of the barge, is provided for the crew. When not placed in the center of the

Fig. 1. "Peniches" on Seine River.

barge, it is placed at one end. The cabin in the center of the barge divides the hold into two parts, but communication between these parts is obtained under the cabin, the floor of which does not extend to the bottom of the barge. All construction above the deck line is very low. A mast is provided where towing is done by animals, but this mast is hinged near the deck to permit of passing under bridges. The péniche is usually built of wood, although there is a tendency to build more generally of steel. It is of much lighter construction than is found in barges of a similar kind in the United States. Most péniches are owned by individual bargemen who live upon the boats with their families, and the members of the family assist the bargemen in the operation of the boat. A few large navigation companies own and operate large numbers of barges, but the crews for these boats are usually made up of bargemen engaged for the purpose who, as in the case of the individually-owned barge, live upon the boats with their families. Stevedores, at the ports, load and discharge the barges or else this work is done with labor provided by the consignor or consignee.

Traction of river and canal barges is most commonly done by either tugs or animals. Upon the larger rivers, tugs are used almost exclusively, while upon the canals, animals are used in hauling barges. Sometimes special mechanical devices are used, but these are applied only upon special lengths of waterways. Upon the lower Seine, between Le Havre and Paris, tugs of from 75 to 500 horsepower are used, but those under 250 horsepower are going out of use for long hauls on this river. The larger tugs tow from four to six loaded barges, the number depending upon the capacity of the barges and the current of the river, because in times of freshets, when the movable dams used upon this river have been lowered, the current becomes very swift. The locks upon the Seine are exceptional for France insofar as they have large chambers which will accommodate at one time five or six barges and a tug. A tug and its tow can therefore be locked through in one operation. The tugs built more recently are of steel and modern in construction. The parts of the tugs above the deck are low and the smokestacks are hinged to permit passage under bridges. The towline from the barges is made fast at a point almost amidship of the tug to permit of easier handling. Except where night work is performed, only single crews are carried on tugs. The use of licensed pilots on tugs is compulsory. Tugs, generally of smaller size and less

power, are used on other improved rivers such as the Marne, the Yonne, the Saône and Oise.

Traction by animals is the rule on canals. At first thought, it might appear that the use of animals at a period when mechnical power is so common is due to an old world tendency to adhere to ancient methods, but such is not altogether the case. The continued use of animal traction is due to these facts: that the locks upon the canals can pass only one standard canal boat through at a time, and that locks are very numerous and the distance short between them.

Fig. 2. Loading Seine River barges at Le Havre.

The use of tugs on canals, where distances between locks are short, would not be economical in time or cost. If a tug towing five barges started on a trip on one of the canals, upon which locks are numerous and pools short, upon arriving at a lock, the tug or one barge would lock through, then each barge would require a seperate passage through the lock. Six lockages would be required to pass the entire tow, and all the barges in the tow would be obliged to wait until the last barge had been passed through the lock. If ten minutes are required to pass a barge through the lock, there would result a delay of one hour at each lock before the tow could proceed. If fifteen minutes are required, there would be a delay of one hour

and a half at each lock. The French consider the passage through a lock as equivalent to the time required to travel a kilometer or 0.621 of a mile. A team of horses can haul a barge on the canals, where locks are numerous, from one lock to the next in less time than that which a barge would be required to wait at a lock for the remaining barges in its tow even if only two barges and a tug constituted a tow. French waterway officials do not consider that any economy in cost or time is attained by tug traction on canals, if the distance between locks is less than 6.21 miles. The average speed of a 300-ton canal boat drawn by a two-horse team is generally placed at 12 miles per day if loaded, and at 19 miles per day if light. Self-propelled barges would not be subject to the loss of time at locks due to waiting for other barges. The speed of a self-propelled canal barge would be reduced in the small canal prisms below the speed which the same boat with equal power would attain in a larger and deeper channel than those found on the canals of France. The hauling of a barge by one or two horses and a driver is cheap traction. If self-propelled barges can attain a speed which will offset the greater cost of mechanical installation and operation, an advantage would be gained by its adoption.

Mechanical tractors operating on the towpaths have been tried but not adopted. It was found that the side pull from the barges caused the tractor in wet weather, when the towpath became slippery, to gradually work so near the edge of the path that there was danger of the tractor falling into the canal. It is stated that it was difficult to overcome the side pull by steering the tractor. It has been recently reported in the French press that experiments with small caterpillar tanks, formerly used by the French army, gave encouraging results. On account of the numerous locks, tractors, to be a success, must be suited to hauling a small number of barges, otherwise long delays would be experienced at the locks as is the case with tugs.

A novel system of cable traction has been installed upon a short length of the Canal de la Marne au Rhin to haul barges through a tunnel section of canal near Toul. In this system, an endless cable, resting on idlers mounted on posts on the canal bank, is driven by electrically operated motors. The towline from the barge is fastened to the moving cable by a specially designed hook and the barge thus hauled through the water.

Upon the Seine River, between Conflans-St. Honorine and Mon-

tereau, a special method of towing is used in addition to the ordinary tug methods. A heavy chain rests loosely on the bottom of the river, approximately along the line of the center of its channel. A towboat provided with a steam-driven drum amidship over-runs this chain. The chain rises from the river and runs over the bow of the boat to the steam-driven drum around which it makes a few turns and then runs to and over the stern of the boat back into the river. The action of the steam-driven drum hauls the towboat and with it its tow of barges. These towboats enjoy a monopoly as far as the method of towing is concerned, and operate under a concession which fixes the rate to be charged for towing. The concession does not exclude tugs from operating on the same parts of the river.

Freight rates upon waterways are not fixed by law in France. The carrying of a cargo is agreed upon and made a matter of contract between the barge operator and the shipper. Shippers are usually represented by "shipping agents" or "affréteurs" who procure barges for the shipper, arrange terms, make the contracts, take out insurance, engage stevedores and attend to the business details connected with waterway shipments. The affréteur is an important agent in the inland waterway traffic of France. He is a link between the barge operator and the shipper. Mutual agreement between affréteurs tends to stabilize freight rates. Without the affréteur individual bargemen would find it difficult at tmes to find cargo for their barges, and shippers would find it inconvenient to secure barges. The bargemen are often not well versed in business methods and the affréteur attends to these for them. Shippers are frequently not conversant with the requirements of waterway transportation or the governmental regulations pertaining thereto and the affréteur furnishes this experience which the shipper lacks.

Navigation upon French waterways is free, that is no tolls are exacted for their use, except in the case of a few canals like certain ones traversing Paris which are operated under concessions; these are authorized to collect tolls. Barge operators transporting goods for others, that is operators in the transportation business, are required to pay annual taxes on each boat based upon the kind and capacity of the boat.

The Seine River, between Paris and its mouth, carries the greatest tonnage of any waterway in France and represents the highest development of waterway improvement in that coutnry. There is, at normal stages of the river, a minimum depth of 9.5 feet between

Paris and the mouth of the river. The distance is 223 miles. Upon the lower 18 miles of the river, between Le Havre and Tancarville, inland waterway craft use a lateral canal which is provided with a maritime lock at Tancarville. From this lock to Saint Aubin, a distance of 16 miles above Rouen, inland navigation uses the river in its natural state, and between Saint Aubin and Paris, the river is provided with nine movable dams with a lock at each. Ocean-going vessels do not use the lateral canal between Le Havre and Tancarville, but use the river as far as Rouen to which point a

Fig. 3. Transferring goods from canal barges to railway cars.

draft of 18 feet can be carried at all times. Ordinary ocean-going vessels can not ascend above Rouen on account of the fixed bridges crossing the river. Except in times of freshet, the navigation between Paris and the Saint Aubin lock is through nine pools formed by the movable dams upon that part of the river. While the dams are up, there is only a feeble current in the river. In times of flood the dams are lowered and the current becomes very swift, sometimes becoming so strong as to interfere with and retard navigation. The principal traffic upon the lower Seine is to and from Paris and points in its vicinity. Much of this traffic is coal brought to Rouen from England and there transferred to barges. Before the Euro-

pean War, Paris was in point of tonnage discharged and loaded, not only the first river port of France, but its total tonnage also exceeded that of any French maritime port. During the year 1913, the year before the outbreak of the European War, the first maritime port of France was Marseilles with 9,832,517 short tons of receipts and shipments combined. Statistics for the same year give Paris 18,146,120 short tons of receipts and shipments combined, or 8,313,603 short tons in excess of the total tonnage received and dispatched at the leading maritime port of France. Of the total receipts, 80 per cent fall in four classes as follows:

Class of cargo.	Short tons.	Per cent of total receipts.
Coal, etc.	4,560,657	35
Mineral building materials	1,301,461	10
Sands, gravels and earth	3,569,897	28
Fertilizing materials and ashes	925,202	7
Total	10,357,217	80

Of the total shipments, 80 per cent fall in two classes as follows:

Class of cargo.	Short tons.	Per cent of total receipts.
Sands, gravels and earth	3,320,749	63
Fertilizing materials and ashes	894,208	17
Total	4,214,957	80

It will be noted that the traffic is almost entirely of the heavy, bulky kind adapted to barge transportation, and it should be stated that in many cases the distances that these commodities are transported in the Paris vicinity are comparatively short.

While most of the barges used on the Seine are of the péniche type of about 300 short tons carrying capacity, there are also used on this river a very large number of barges of greater carrying capacity, some running up to about 1,650 short tons. Barges of from 550 to 770 short tons capacity are very common upon the lower Seine. These larger barges are usually engaged in the coal

carrying trade. They are similar in type to the pèniche but are of steel construction and more substantially built. They are generally non-propelled. Instead of being owned mostly by individual bargemen, they are the property of navigation companies. Concrete barges of from 715 to 1,650 short tons carrying capacity have been built during the war for use on the Seine, and while some of these are in use, they have not as yet become numerous. Freight-carrying steamboats, similar to those used on many rivers of the United States, are almost unknown in France. In the Paris region, large numbers of fast passenger carrying steamers, known as "bateaux parisiens," ply between different points in Paris and its vicinity. A line of specially constructed steamers has been established between England and Paris and at the present time there are four of these used. These steamers are strongly built for navigating the English Channel, are of shallow draft for the Seine river, have low decks, so as to be able to pass under bridges, and have their smokestacks and masts hinged, so as to permit of lowering when passing under bridges. This line of boats is an example of combined ocean and river navigation.

At the more important river and canal ports, facilities exist for the loading and discharge of barges and often for the transfer of freight between barges and railroads. Dock walls are provided, alongside of which barges may be moored. Cranes are found on the docks for the loading of freight and, where there is railroad connection, railroad tracks run alongside the dock walls. Warehouses or sheds are sometimes provided for the storage of goods. The importance of transfer between railroads and waterways is realized by French waterway officials and others engaged upon waterway transportation. The newer ports established contemplate railroad connections wherever railroads pass near enough to make railroad connection feasible. While the larger river and canal ports have good facilities for the loading and discharge of freight and often for its transfer to and from railroads, the smaller ports, as a rule, have few or no appliances, due to the fact, no doubt, that the tonnage handled at these is small.

The improvement of the rivers and canals of France and all functions pertaining to operations thereon, fall under the Minister of Public Works. The personnel directing these works and operations, are engineers taken from the engineers of the Ponts et Chaussées, corps of engineers educated for the purpose of designing, ex-

ecuting and administering the public works of France, at the École National des Ponts et Chaussées. These engineers receive a very advanced professional training, and their corps has acquired an enviable standing among the engineers of the world.

Like in the United States, traffic on waterways has suffered from the competition of railways. Efforts are made from time to time by advocates of waterway transportation to secure the amelioration, enlargement or development of certain water routes in order to stimulate or revive traffic on them. Congresses are held occasionally with this object in view.

Many French waterway officials are of the opinion that their waterways should be improved to accommodate larger boats; that upon the canals larger and deeper channels should be provided, that the number of locks should in many cases be diminished, and the lengths of pools thereby lengthened, by giving locks a greater lift. Whether a sufficient increase in traffic would result from the enlargement and amelioration of many of the waterways to justify the cost is an open question. It will probably be justified on the Seine, between Paris and its mouth, for which work a project has already been approved and funds provided by the French government.

Upon the whole, waterway traffic in France has not held its own and advanced to the extent that its advocates desire. Where there are large quantities of heavy, bulky material to be carried, good use is made of them, as on the Seine and upon the canals in the north and east of France, but where this class of freight is lacking or is to be carried only in limited quantities, the railroads carry nearly all the traffic. In this respect, waterway conditions resemble those in the United States, where heavy bulky freight constitutes the larger part of the freight carried. A larger proportion of light freight is, however, carried upon the waterways of the United States than upon those of France, because this class of goods is here carried on fairly rapid combined freight and passenger steamers, a class of boat not adapted to waterways with numerous locks and low fixed bridges, as are frequently found in France.

The waterways of France have played an important part in its economic life in the past and will probably continue to do so, but in France, as elsewhere, freight better adapted to the railways has gone and will continue to go to the railways, and freight better adapted to water transportation will seek the waterways where these provide the necessary facilities.

THE DIVISIONAL ENGINEER OFFICER AND HIS RELATION TO THE ARTILLERY AND INFANTRY.[1]

Gentlemen: The subject given me on the topic sheet is "The Divisional Engineer Officer and his relation to the Artillery and Infantry." Our "Tables of Organization" provide that the functions of the Chief of Artillery and the Chief Engineer on the staff of Division Commanders be performed by the Commanders of the Divisional Artillery and of the Divisional Engineers, respectively.

GENERAL DUTIES.

As an ex-officio staff officer, the functions of the Divisional Engineer are to foresee the engineering problems which may face the division and to provide the tools, materials, trained personnel and plans for the timely solution of these problems. Primarily, however, he is the Commanding Officer of the engineer regiment and the engineer train, and as such is directly responsible for their discipline, training and proper functioning on all occasions.

The engineer regiment, as you know, is armed with the rifle and, for purposes of discipline and to instill into the regiment the spirit of combat engineers, the men are drilled and trained as riflemen.

The regiment is not given to the division as an extra regiment of Infantry. The infantry drill is a means to an end—not the end itself. The rifle is part of the engineer soldier's equipment, must be his for use in emergencies, but the engineers can normally aid their division most by doing the work for which they are specially trained and equipped.

As I have said—the functions of the division engineer are to foresee and provide the engineer tools, materials and works needed. These are also the functions of the engineer regiment and train. The Division Engineer has no duty which he can accomplish without his officers and men. As a matter of fact, the Engineer Regiment is the Division Engineer—not the Colonel alone.

[1]A lecture delivered by Col. George R. Spalding, Corps of Engineers, at the Army Center of Artillery Studies, A. E. F., March 3, 1919.

If they are properly trained, properly imbued with the spirit of auxiliary troops, they will do their work well. If they realize that the regiment has no reason for existence except for the division, we will hear little complaint.

Engineer troops can not be given this spirit of service, this divisional spirit, if they are trained at a special engineer training camp. They may learn there to be good road builders, good bridge builders, good all-around engineers, but they will never become good divisional engineers, good combat engineers, until they live with and become a vital part of their division.

In the early days of the organization of our new divisions in the United States, the engineers living as part of the new divisions were undoubtedly frequently misunderstood. Every one pretty well knew the functions of the Artillery in battle—they were to support the Infantry with their guns. Few knew exactly what was to be done with a full regiment of Engineers. There were two battalions of them in the regiment. Was one battalion to be assigned to each Infantry Brigade? That seemed logical and yet, if so, who would do the engineering work needed by the artillery or the general work needed by the Division as a whole?

And what work were the Engineers to do? Were they to build the bridges? Everybody agreed that they were. Build the roads? Yes, but all of us thought that the splendid system of roads in France would not require the work of a full regiment of engineers for each Divisional Area. Were they to dig the trenches? No, the men who fought in them were to dig them. Were they to supervise the digging of trenches? Why could not the Infantry Officers do this themselves? They had passed through a course in trench construction quite as thorough as the Engineer Officers had, a little more thorough, perhaps, as they had special officers who had been in France, lived in the trenches, fought in them; others who had been to a field fortification school at Fort Sill, had learned there all the latest styles, talked about saps, trench mortar emplacements, shelters, duck-boards and the like with very embarrassing familiarity. Were they to supervise the construction of the camouflage of the battery positions, the construction of dugouts for the gun crews, the P. C.'s? Apparently not, as the Artillery had assigned to them special instructors in this line and were proceeding under splendid camouflage discipline to construct all of these things with their own men.

While worrying about these things, one Engineer Officer found that everyone wanted engineer supplies of all kinds, and quantities; that roads in the cantonment were getting bad; that the roads at warehouses were impassable; that the water supply of cantonment was intermittent and perhaps questionable; that the lighting system in camp was on a rampage, lights had a habit of going out just when the staff needed them most; that the surgeon was complaining of undrained areas in camp dangerous to health; that the Infantry were getting their rifles and would soon need a target range; that the cantonment was not large enough to offer a target range for the Artillery but that one must be had; that contoured maps of the cantonment and surrounding country were vitally necessary for training in tactics and a careful survey of proposed Artillery range was needed.

He also found that the Divisional Commander, being responsible for the training and health of the Division, was responsible for all of these things and that, while other agencies were charged with some of them, the Division Commander and the Division as a whole looked to their Division Engineers for plans to the solution of the Engineer problems facing the Division and its sub-units.

In my opinion, this was the beginning of the real "sure-enough" training of that regiment of divisional engineers. The many demands required a placing of responsibility for service upon the officers and men of the regiment.

By a gradual process of development, the engineering needs of the Division came to be looked after in much the following manner: To each Brigade of Infantry a battalion less one company was assigned, one company to each Infantry regiment; to the Artillery, one company; to the Division Dump, one company and motor section of train; to look after the needs of the Division P. C. and Divisional Engineer himself, the Headquarters Detachment; the horse section of the train was released to the companies as needed by them.

It will not be understood that the regiment was split up in any such manner. It was quartered together when possible and handled as a unit. The Majors and Captains, however, kept in close touch with the needs of the troops to which they were assigned. In training areas, in battle, in rest areas, these officers saw to it that their units had their proper proportion of engineer supplies and tools, that the road system in the area occupied by their unit was kept up; that the shelters were secured and erected as needed.

This system led to a close co-operation. The Major and Captains began to feel that they owed a special sort of loyalty to their Infantry or Artillery Commanders; that it was these men who were going to fight the battles and that they were to help; that by working with them, training with them, doing for them always the best they could, they were making for the success of the Division.

PREPARATION OF SECTOR FOR DEFENSE.

In our new provisional drill regulations for Infantry, we learn "that an Infantry that knows how to attack well knows how to defend," "that all training should aid at developing positive qualities of character and action rather than encouraging negative traits" and "that the basis of training will be the attack."

This was the doctrine of the American Army when we entered the war and it was the doctrine which the A. E. F. insisted upon and carried out against many handicaps. But we all similarly recognize that on some parts of the field there will come the time when the advance of our troops is definitely stopped. Under such conditions, our Infantry Drill Regulations say "the Brigade Commander takes steps to organize his troops in depth, if the situation requires such action. Depending on the character of the hostile reaction anticipated, he disposes his brigade in one or two positions. In the latter case, either pursuant to instructions from higher commanders, or on his own initiative, he fixes on the line of resistance of the outpost zone and of the main position, assigns zones of depth to his regiments, arranges for Artillery support, and organizes his machine-gun defense of the intermediate zone between the two positions. He organizes the defensive works to be constructed, determines on the order of their construction, details laboring parties, and allots the necessary engineer personnel and material to the different positions." That is the function of the Brigade Commander and not of the Division Engineer.

After an attack in thick country, it is quite impossible for some time to determine with any degree of accuracy the exact line held by our advanced troops. There will be a zone varying in depth in which constant patrolling is going on, constant exploitations by our own troops are being made. In this zone the organization in depth will be made as rapidly as is possible by the Infantry under their own immediate Commanders, who will insure contact to right and left. Once distributed into an outpost organization, the troops will dig in, with their portable tools, as best they can.

In rear of this outpost position will be organized what may be called a battle position or the main battle position. The location of this position may be given, and usually will be, by the Corps as a single line on a map running from wood to hill, to wood, to villages. In the rear of this, the Corps will also undoubtedly provide for the organization of certain woods, hills, villages or other areas of tactical importance, into strong points.

The Brigade Commander will concern himself most with the line of resistance. He, with his Adjutant, Machine-gun Commander, and the Major of Engineers, will study the line as laid down by the Corps and proceed to carry out the plans of the Corps in spirit. It will be understood that this line is not a continuous trench line. It is a wavy line running from strong-point to strong-point; a line which gives machine-guns, automatic rifles and rifles full play. A line laid down actually on the ground to connect up combat groups which have been determined upon as vital by the Battalion and Regimental Commanders.

This line once roughly laid out, the job of the Engineers is to get a line of wire in front of it; get the wire up from the rear and get it placed. That is particularly the job of the Engineers. Also, to get shelters up for the Brigade P. C.'s, to help the pioneer platoon with materials, labor and advice in getting Regimental Commanders safe. In the same way to look after the posts of Battalion Commanders and the Artillery, is the job of the Engineers.

But most important of all is to get *communication* to the *rear*, by trail, cross-country track or main road. Next to get water points established. Next to get the tools issued to Infantry to dig the combat positions along this line of wire. I think that too much stress can not be laid on the point, that it is with men, food, ammunition, that the reaction of the enemy is to be stopped. All the wire in the world will be of little avail if ammunition, water and food are not brought up. No line can be perfect, too much searching for the ideal will result in nothing being done. What is wanted is a line decided upon, a line of wire in front of this, protection for the posts of command and good communications. Let the Engineers avoid giving too much advice to Infantry and Artillery Commanders. There was a little temptation on the part of the young officers to advise the Infantry Colonels where and when they ought to dig in. What they wanted the Engineers to do was to get the stuff up and get the wire up and they were not very anxious about

that until they were sure water and ammunition were up. Let them get in the wire, get good communications, get tools and materials up, get water points established and the rest can be left to the men who have devoted the greater part of their training to tactics.

In this organization how do the Engineers work with the Artillery? In the same way. The Artillery needs roads and trails to their batteries; they will, in the early stages, take care of their own camouflage, their own gun positions. The Engineers will help in getting up materials for the command posts and in issuing tools and sand bags to them. Insofar as may have been possible these materials, camouflage and sand bags will have been actually issued them before the advance, as should also be canvas water troughs to each battalion and a hand-pump or so, in order that animals may get water.

During the time when the Engineers, with the assaulting Infantry and with the forward Artillery are helping on the forward roads, the Division Engineer with the other companies of the regiment and with such troops from corps as he can get will be working on the main road of the division and its branches to the Artillery and Infantry Regiments, trying to tie up with the forward Engineers working back toward them.

PREPARATION FOR OFFENSE.

We hear frequently that Engineers must not be attached to assaulting Infantry, or to Artillery, that they should be held in hand by the Division Engineer for work on main lines of communications and as a working reserve for emergencies.

Particularly is this true in certain publications issued by our Allies. They advise that the Engineers should not get up too early, that if they follow the assaulting line too closely they get mingled with the assaulting troops, begin to use their rifles, and become practically a part of the Infantry line. Also the Infantry Commander, seeing a considerable body of Engineers behind his line, uses them as reserves. Therefore, the Engineers should not move up, according to the manuals, until nightfall.

I think this is bad doctrine. It sprang from position warfare where things do not go very rapidly.

If some of the Engineers do not get across with the Infantry, the Divisional Engineer is not going to find out much of what is going on in front or is not going to do very much to help the In-

fantry. There will not be any trouble if the Engineers have a job to do and if they have been told what that job is. Once the job is done it does no harm to let them take a little bit of shooting practice. It does good.

In assigning the Major and his two companies to the assaulting brigade it will be understood, of course, that these two companies will not all go over with the first wave. The Major, discussing with the Brigade Commander, and the Captains with the Regimental Commanders, will decide upon the organization of proper wire-cutting parties which will be probably made up partly of Engineers and partly of Infantry and, preceding the battle, these little wire-cutting parties will be equipped with wire-cutters, axes, and whatever the Regimental Commanders feel they ought to have and the Engineers and Infantry, together forming the parties will have some training if they can, in what they are to do if they run into wire.

If there is a creek or piece of swamp to be crossed the Captain after discussing with his Regimental Commander will provide some sort of foot bridges to get the Infantry over in time. Of course these little foot bridges are make-shift affairs. The Infantry, unless they have used them, do not have much confidence in them. So practice in placing and using them must be had by the assaulting troops.

The number of men required for the wire cutting and bridge building will not, by any means, take up the two companies assigned to the assaulting brigade. The Major will hold from each company a couple of platoons and these will be put, immediately as the advance proceeds, on the main road leading up to the two regimental positions.

The time of advance for the Divisional Engineer himself and his reserve Engineers who will work on the main road depends on the conditions of the main road. In the attack in the Argonne in September, as you all know, the troops were going across a "No Man's Land" which had existed as such for four years. The roads in the sector of the division to which I had the honor of being attached did not run straight to the front. Unfortunately they came in at an angle and then went out at an angle, so that they were practically parallel to our trench system and the enemy's. The ditches of these roads had been used by our troops and the enemy for rifle trenches and communication trenches. They dug the ditches a good deal deeper and threw the dirt on the road. We

found the old metal road covered with from four to six feet of soft dirt. We did not know where the road was until we sounded down to it. Altogether the three companies which I had left and three companies of pioneer Infantry from the corps had to spread over 15 kilometers of road that day. That is pretty thin. I found out why we had a full regiment of engineers with the division that day. Later in the fighting, as we got through "No Man's Land," of course, the road condition was better, particularly was it better during October when we were not advancing very fast. The roads, however, needed constant attention so that the entire engineer regiment of that division was on the road every day.

There has been a good deal of discussion as to how in map problems and how in actual campaign the Engineers shall be used. I have had a number of officers ask me the question, "How in such a problem, would you use the Engineers—would you put them in reserve with the Engineer Colonel in command of the reserve"? I think there is a little bit too much tendency to believe that you can find out what the Engineers can do from the map. That is one job you can not find out from the map. You can find something from the map, of course. You can find where the roads, when the map was made, ran. You can not find from the map what the condition of the road is. You can find from the map where bridges were when the map was made, but you cannot tell whether that bridge is still there. If you put your Engineers in reserve you will find the Engineers living very comfortably in reserve for four or five, six or eight hours, a little nervous may be through the first hours of the attack, but comfortable and safe and well-fed.

And then you will find suddenly that the people up in front are not well-fed, that something has happened to the food trains, something has happened to the ammunition train, and then of course the Engineers will be taken out of reserve and put on the roads, but they have lost six or seven hours of work and that loss may have been vital.

In one case I know of a regiment—I am not going to mention any names—in the G-3 order was put in reserve and the Engineer Colonel in charge was ordered to a certain ravine. That Division was attacking across a marsh. Across that marsh ran a road embankment. The Germans had blown up that embankment; there was a crater every 100 meters or so. Fortunately the Colonel of this particular Engineer Regiment was interested in this. He got some of his men out to have a look at it. He then went to his Chief

of Staff and told him that he was in reserve and that if he was not taken out of reserve and put to work on something to get across that marsh that his Infantry would starve and his Artillery would never get ammunition. He was taken out of reserve and worked all that day with hardly any material and built a sort of road out of brush and corduroy. Later there was sent up road planking, and 3,000 feet of plank road was laid across the marsh. I think it might be possible, if the Engineers must be mentioned in G-3 order, to mention them in some way as the Artillery is mentioned—"the Artillery will support the attack." I think if we could have a G-3 order read something like that the engineer work would be better done.

I do not mean, Gentlemen, for a moment that the Engineers should never be put in reserve or used as Infantry. They are armed with the rifle, they are able to shoot with it. They have not the automatic rifle, they have not the instruction for working in liaison with the machine guns, but at the same time the Engineer Regiment is 1,600 rifles and if the Division has been in for awhile that amounts to something. Some of the Divisions in the Argonne got cut down to 300 or 400 men to the regiment. Under such conditions, if the Division must still stay in—and it must at times—the Division Commander must put in the Engineers as Infantry and it is a question for him to decide and he is going to decide it as between the desirability of having the roads a little bit better or the desirability of throwing in 1,600 fresh men to take one more hill or one more bunch of woods before night. Similarly, when a reaction starts from the enemy, the Engineers are going to be used not only to dig but to actually defend a second line. So that if anything happens to the Infantry on the front line there will be someone back there with rifles to stop the counter-attack. The Second Engineers were used that way to wonderful advantage in the Chateau Thierry fight. In two or three cases in the Argonne, Engineer Regiments were used to dig rear positions and actually hold them. There the attack did not come all the way through but they were there digging a trench and ready to use the rifles had it been necessary.

IN TRAINING AREA.

I think we may sum the whole question up, Gentlemen, by saying that the Engineers are trained and equipped to supply materials, to do construction for the Division, to take care of roads. I do not mean by that that the Engineers are going to be able to do

all the work for a Division. When we move into a new area we find there is no shelter anywhere. All the regiments that have horses want horse shelter immediately. They want shelters for their men for mess halls, cook shacks, etc. Now, if you wait until the Engineer Regiment does this work for you—you will have a long wait. It is the engineer's job to get the materials and distribute them throughout the Division under supervision of the Chief of Staff, not with his own transportation alone, but with the transportation of the units that want the shelters. He has not enough men to put up all these shelters, but he can put up shelters for Brigade and Division Headquarters and provide enough skilled men and tools to assist the Infantry.

It is the job of the Division Engineer to systematize the road work, cut up the area into sub-areas assigned to the particular unit using that area. The Engineer Officer assigned to the work in that area does not do the work entirely with his own men. He sees that the Infantry gets the material and that the skilled work is properly done. Then in addition to that, the Engineer Regiment takes care of the many general works in the Division, such as the roads to the rear and to the hospitals nearby.

DISCUSSION.

Col. C. O. Sherrill, Engineers (by letter).

On account of the different conditions under which engineer sapper regiments operated during the recent war, it appears that there were almost as many different methods of co-ordination with the other units of the division as there were different sapper regiments. The methods proposed above by Colonel Spalding are probably based upon the system developed by his regiment during the time that he was division engineer, and which for the conditions met by that division worked satisfactorily.

There are certain principles enunciated in his paper which are of great importance to every division engineer, especially his insistence that team work between the engineers and the line is an absolute essential to the success of the engineer operations in a division. Without this complete understanding between the line commanders and the engineers, the engineer regiment is relegated to a minor rôle and exerts a limited influence on the general solution of the problem before the division. While there is an entire agreement by all troop commanders and staff officers as to the

necessity for this coöperation, there are many different opinions as to the best methods to be used to secure it. I can not agree with some of the detailed methods suggested in the above paper, particularly as to the desirability of assigning certain units of engineers under the orders of brigade and regimental commanders of infantry and artillery. To assign a battalion under the orders of a brigade commander, is, in my opinion, a fundamental error of policy for the reason that the brigade commander may, perhaps, not use it to the best advantage, and having once placed it under his orders, the battalion is not so readily available to carry out the wishes of the division commander as transmitted to his division engineer. Nor, for like reasons, does it seem advisable to assign a company to each infantry regiment or to the artillery. The engineer regiment has a large amount of work to do for the division as a whole in active operations, whether in a sector of trench warfare, temporarily halted in a position being strengthened against possible hostile attacks, or an agressive offensive, and it is only by holding the bulk of this force in the hands of the division engineer that the needs of all parts of the division can be effectively met. The division engineer should, in general, direct his battalion commanders to report to the brigade commanders in order to furnish assistance and coöperation in every possible way. These battalion commanders should have their headquarters normally at the brigade headquarters. The plans of the brigade commander should be known at all times to the battalion commander, and the brigade commander should feel free to call upon the engineer battalion commander for advice and engineer assistance, but this should be done as a matter of liaison and not because the engineer troops are under the brigade commanders' orders. Both methods have been tried, but once the battalions are placed under the brigade commander's orders, it becomes difficult to coördinate their work or to assign them to duties more important for the division's welfare if this happens to interfere with the plans of the brigade commander.

As an example of the necessity of holding the bulk of engineers of the division in the hands of the division engineer, let us take the case of the advance of a division in the Argonne offensive. This advance contemplated the crossing of a heavily fortified area which had been occupied for four years. It was necessary for the division engineer to make plans not only with regard to communications for the leading elements of infantry, but also for the early

advance across the fortified belt of the artillery and supplies. It therefore became necessary for the division commander, in his orders, to specify the size of the small units that would be attached to the advancing infantry, to provide openings through the barbed wire and across obstructions, and to provide communications to the rear for these units. It also was necessary for the division engineer to plan an order of operations for the remainder of the regiment, and for such additional labor troops as would be furnished for opening the Artillery roads according to a well considered plan. The result secured was entirely satisfactory, and the artillery were able at all times to keep close up behind the infantry, even with their 155s.

The system followed when the division occupied a defensive sector, and which worked to the entire satisfaction of all, was to have the battalions and companies stationed so that they could function in close liaison with the brigades and regiments of infantry, with which they had become well acquainted. But as above mentioned, the engineer units were entirely independent of the infantry commanders. In this quiet sector, the engineers constructed a large number of dugouts of all types varying from hard rock construction, using air drills to cut, and covered dugouts and those of reinforced concrete. Infantry working parties were frequently assigned to assist as carriers and laborers. The division engineer was responsible for the general line of entrenchments to be constructed, and on his recommendation these lines were established by the division commander, the engineer battalion commanders being responsible for the accuracy and correctness of the location and type of works of the portion of the line within their corresponding brigade sector, according to the plans approved by the division commander. An engineer officer was assigned to each infantry regimental area with a number of non-commissioned officers as assistants and it was their duty, under the engineer battalion and regimental commander, to see that the plans, as approved, were carried out, to report the number of men working, and to make recommendations for improvements. The infantry commanders were required to execute the works and had complete control of their units in doing so. This was the system that was worked out as a result of many modifications of method of control.

The first method tried was for brigade commanders to have absolute control over the lines of defense within their sectors. It was difficult under this plan to arrange for points of termination

of brigade responsibility, or to coördinate the different ideas as to what the defensive developments should be. The experience of a division which occupied a defensive sector of normal frontage may be taken as illustrative of this difficulty. The defences, existing at the start, consisted of the usual outpost position with support of reserves positions to the rear, all with from one to three lines of trenches and wire. In planning the ameliorations and improvements of the existing systems the ideas of non-technical commanders concerned varied from satisfaction with the system as taken over to a desire to see it entirely reconstructed. Their radically opposed views involved so many difficulties of coördination and such lack of continuity in the proposed finished defenses that the division engineer was called upon to devise a general plan of improvement and was finally given responsibility for its execution. In this way developement and coördination satisfactory to all was secured, and the work proceeded smoothly under technical supervision.

Even after this decision, however, the infantry commanders were held solely responsible for the amount of work turned out, with the result that some companies and battalions immediately secured good results but many of them accomplished almost nothing. The division commander thereupon found that by authorizing the engineers to designate the order in which the work should be done set tasks and submit reports on the amount done by each organization an immediate improvement was noticed, both in character and quantity of work performed. In this same sector the engineers had charge of the camouflage of dugouts, were called upon to assist with officers and non-commissioned officers, in the construction of dugouts and camouflage for the artillery at a time when the Artillery had every moment of their time taken up with the operation of their guns. If special training is worth anything at all, or if works are to be built involving the most advantageous methods and best use of materials, it is certain that men who have had engineer training and experience should supervise the work and these men naturally will be found in the engineer regiment. It does not require a skilled superintendent of construction to be a good artilleryman or a good infantryman, but certainly he will make a good field engineer.

The method finally worked out for the prompt location and execution of work on a defensive position which was placed in a state of defense during the exploitation immediately after an ad-

vance was as follows: One company of engineers was assigned to the outpost sector of each brigade charged with the duty of constructing; first, barbed wire in front of the infantry outpost; then, locating and assisting the infantry in constructing small firing pits on this line, later extended into platoon trenches. These engineers were quartered between the outpost and support line and worked constantly without relief for more than a month, during which time all of the units of the infantry in the division had taken their turn at the front. In the same way one engineer company was assigned in each brigade area to the support position and one each to the reserve position. The headquarters company and train were constantly employed in furnishing supplies and materials for these positions and in constructing water points, preparing maps, and other reproductions for the division, so that each unit commander down to the infantry platoons, were supplied with first-class maps of their respective areas.

For the location of the various lines of this position, the division received from the French corps previously occupying the ground the main points to be held and the general lines to be developed, the points of joining up with right and left defense being exactly determined on the map by the French Corps Engineer and American Division Engineer and later being verified and definitely fixed on the ground by the division engineer in conference with the infantry brigade commanders and engineer battalion commanders. The division engineer would then designate the point of junction between the brigade sectors in conference with these commanders and would, with each brigade commander and the corresponding engineer battalion commander, go over the brigade line and definitely locate it on the ground within the reasonable limits. Details of location were properly left to the initiative of the infantry regimental and engineer battalion commander. The wishes of the infantry were considered in every instance, and no effort was made to force something on them which they did not want, but the necessary coordination was in all cases secured by decision made by the engineers. When the line was thus located, the engineers immediately set to work taping it out, and assigning company tasks for the infantry; at the same time parties were put to work placing wire in front of the entire line. The method followed was to place a simple fence thrown up as quickly as possible at the limit of the band of wire to form a protection for the workers on the trench in case the hostile counter-attack should be suddenly launched. After

the completion of this first wire fence, it was extended towards the rear, step by step, until the entire entanglement was completed. This was the procedure followed by my division in operations upon the Vesle, upon the cessation of our advance on August 10, 1918. After this method of operation had been once tried, there was little if any objection to it on the part of the unit commanders who realized the necessity of having the engineer coordination and supervision under the division commander. In other words, it was a division problem rather than one for separate brigades or regiments.

During this period in preparation for a later advance, supplies and materials of all kinds were being brought up and stored in advance dumps, as close to the line as animals could safely be taken. At this time standard trestle bridges were built, capable of use as single span or extension into a number of spans; floating foot bridges were assembled capable of providing at least 3 for each infantry regiment. These were made of captured German cylinders or small gasoline cans. At the same time there was considerable amount of the trestle equipage belonging to German ponton trains, which had been captured at Chateau-Thierry, brought up and assembled. During the time of occupation many foot bridges were placed across the Vesle for patrol purposes by the infantry. These were all built under the heaviest kind of machine-gun artillery fire, and of course had to be rebuilt frequently because they were destroyed almost as fast as erected. When the advance commenced, four artillery bridges were thrown across the Vesle. One of them with German equipage was built and ready for use within 3 hours after the order for advance had been given. This bridge carried not only a large part of the artillery and transport of the division, but practically all of the transport of the French division on its left. During the first night of the advance this bridge permitted the advance of enormous quantities of artillery material, including both 75s and 155s.

Another important function of the engineers in this advance was the examination and neutralization of German traps and mines. The country rock between the Vesle and the Aisne is of limestone, and was honeycombed with old quarries of large size. In almost all of these the Germans had planted infernal machines of one kind or another, some of high explosives and others of gas. All these had to be cleared and declared safe by the engineers before the troops were allowed to use the shelters. One of these quarries was

occupied before it was declared safe, with the result that 100 enlisted men and a number of officers were badly gassed. One of the engineer companies lost five men from the explosion of a mine discharged during the first night of this occupancy by one of the men stepping on a concealed spring in the floor of the cave.

This same sector, when taken over by my division, contained some 25 or 30 dumps comprising all kinds of engineer materials. Some of these were under the engineers, some under the artillery, and some under the infantry, the materials having been drawn for certain specific jobs but not used, and subsequently controlled by the organization who drew them. These dumps were all taken over and held by the engineers. A main divisional dump was established near division headquarters under the control of the division engineer. Two brigade dumps near brigade headquarters under the control of the engineer battalion commanders, one regimental dump for each infantry regiment under the control of the engineer captain in liaison with that particular regiment. Instructions were issued permitting any infantry or artillery officer to draw necessary materials on application to the nearest engineer officer who was authorized, without reference to higher authority, to issue orders on these dumps for all normal requirements. For extraordinary requirements—as for extensive structures which had not been approved—the engineer officer would telephone to the division engineer office explaining the case, and recommending action. In this way large quantities of material were saved by preventing structures from being started which were unnecessary and not in accordance with the division commander's general plans. However, there was the greatest freedom in issue and no infantry or artillery officer had occasion to complain that he could not secure materials. Some difficulty was at first experienced with camouflaged material, as that was not under the absolute control of the division commander, but later when the camouflage officer reported direct to the division engineer this material was handled in the same way. If an artillery regimental commander wished to build some batteries, the camouflage officer would be sent to look over the situation, estimate for the necessary material, draw it from the nearest engineer dump and supervise the erection of the camouflage. In almost all cases, units requiring materials hauled them with their own transportation from these dumps. The engineer regimental and train transportation was constantly engaged to the limit of its capacity in supplying these dumps from the rear.

The question as to the propriety of using engineers as infantry is an important one. The engineers form a valuable asset for this purpose in case of great emergency, but should never be so used unless the emergency is most pressing, for the reason that the service they can render on engineer work with the division is so important and so constant that they can rarely be spared for diversion to infantry work. They should, however, be armed with the infantry rifle, and trained in infantry tactics for the purpose of being prepared, but more especially for the disciplinary advantage gained by this training. There is no doubt about it that intensive and *strictly executed* close-order infantry drill is the most effective method possible for securing team work in an organization and a high state of discipline. Men in this way become better acquainted with their fellows and with their officers than in any other form of training. There is frequently a temptation to place engineers in the battle line as it is the simplest and easiest method of securing decorations and commendations, but this is scarcely a laudable motive in itself and does not normally lead to a proper use of engineers. In this capacity, they can not contribute to the division and army the valuable services that can be given by performing their proper functions as engineers.

In an advance the division commander, on the recommendation of the Division Engineer, makes assignments of the small groups necessary for accompanying each assaulting battalion, and after other special details have been made, the bulk of the engineers and all unemployed labor troops available are used for making passable the roads within the divisional area. These divisional engineers should be followed up by corps and army troops whose duty it is to make more extensive improvements in the roads required by the heavy traffic to which the latter are invariably subject. This work is done in a deliberate and systematic manner by the army troops, who should have an abundance of materials and transportation available for the purpose.

The Engineer units should be so equipped with transportation, engineer tools, and especially with cooking outfits that every unit, no matter where it goes or how near the front it operates, will always have adequate means of furnishing hot meals to its men. In my own unit this was accomplished by abandoning all rolling kitchens and taking in exchange for them English light limber wagons so that each platoon had a limber wagon, and cooking utensils for 3 days' rations. These cooking utensils consisted of

"Dixies," and the necessary knives, spoons, etc. These "Dixies" form an extremely valuable cooking utensil, for they combine in themselves the advantages of cooking pot, frying-pan, and baking pan. I wish here to record my whole-hearted opposition to the use of rolling kitchens for mobile troops and especially for engineer troops. A rolling kitchen is a useless and cumbersome item which requires alone as much transportation as should be used for carrying all of the cooking utensils of the company, and its supply of rations.

The commanding officer of the divisional engineer regiment is a colonel who is ex officio division engineer. These two functions, each of which is of great importance, are closely interconnected and can only be executed satisfactorily if the officer who has these duties keeps in the closest possible touch with the division commander and chief of staff, while at the same time he exercises a positive and effective control over his regiment. This can be done only if the the engineer regimental headquarters are located in the immediate vicinity of the division headquarters. This method was followed by my division in France, and as a result there was the closest harmony between the division headquarters and regimental headquarters. All of the map reproduction and mapping work required by G-2 was executed by the engineers on request, the liaison between the commanding officer of the headquarters company and G-2 being of the closest character, so that every need of the division for maps and reproduction of all kinds was promptly supplied. In some divisions the division engineer almost abandoned the command of his regiment, turning it over to his lieutenant colonel, who had the regimental headquarters several miles away from the division headquarters. In other divisions the commanding officer of the engineer regiment stayed with his regiment and was not consulted in the preparation of plans for division operations. He could not know anything of the division commander's tentative plans and therefore had little influence on the division operations even as affecting his own regiment.

In conclusion it appears to me of vital importance that the proper doctrine as to employment and administration of division engineers should be incorporated in our future text-books. This would prevent leaving so much to the personal equation of the division commander and the division engineer. There will always be enough scope for exercise of the imagination of both without

leaving everything connected with the proper use of engineers entirely to chance or to the mood of the moment.

Colonel S. H. Acher, Engineers (by letter).

I fully agree in the foregoing discussion by Colonel Sherrill, with the exception that in my experience it was frequently more convenient to the companies to maintain a regimental headquarters directly under the lieutenant colonel and at some distance from division headquarters. This was in case the division engineer maintained a separate office at division headquarters and was the plan most often used by the 4th Engineers.

Col. G. B. Pillsbury, Engineers (by letter).

This paper has so clearly explained the duties of the divisional engineers, and their relations to the other combat arms, that little is left for discussion.

The author of the paper rightly points out that engineers can not exist alone—they are useless by themselves—they must depend on the infantry for the information that they must have to carry out their work and for the communications to transmit their reports and instructions. If the engineers and infantry are on cordial terms they can get information, they can get their messages through, and they will be welcomed in the cramped P. C.'s.

The proper relationship may be gained by the cordial cooperation of the engineers in all the big and little jobs that must be done to make life reasonably happy in training camps and areas. In doing such jobs, or in helping do them, the engineers should do them in the way that they are wanted done. If a brigade commander has made up his mind that a walk or road should be built in a certain place, the engineer's first idea should be to put it in that place—not to find a better place.

A second method for securing the proper relationship between the engineers and the other fighting branches is to absolutely eschew, as a matter of principle, criticism of these branches. When the millenium comes, we may find infantry that likes to dig trenches under our direction, and that will not use for firewood the revetments, huts, etc., of which we are so proud; but when the millenium comes we understand there will be no use for combat engineers. In the meantime we must take things as they come. To be sure, nothing seems so harmless as to amuse ourselves, in the sanctity of our messes, with criticism establishing our superiority over all others—

it will never get out, and where's the harm? But the next day our manner, or the manner of a young second lieutenant, closes the gate of confidence between ourselves and our fighting neighbors and when the day of combat comes we lose men in executing useless tasks, because we are not one of the team. If you have not confidence in your neighbor, he certainly will not have confidence in you. And if the infantry and artillery in your division are really bad, there is no use in talking about it, for the division, and the engineers with it, will fail.

It has been my experience that an engineer regiment—or any engineer officer—may be rated by the opinion that the regiment or the officer has of the infantry and artillery and staff of his unit. If the engineers rate the infantry and artillery high, if they have confidence in them, one may be certain that the engineers are first class. If one hears among the engineers constant criticism of the line and staff, one may be equally certain that the engineers will fail in the pinch.

The third method of securing teamwork between the engineers and the other branches is to keep the latter informed on what you are doing and going to do. The division engineer must issue instructions daily to his units, giving them their missions for the next day. It is much better that these be written, and that each of his next subordinates has in one memorandum the mission of all the other engineer units as well as his own. The division staff should have a copy of this memorandum, as should all commanders within whose territory the engineer units are operating. We are likely to criticise the general staff for not telling us in time what is going to happen, but we are prone to the wholly mistaken belief that they are not interested in what the engineers are doing.

Cordial cooperation with the other fighting branches, founded on mutual respect, is the first fundamental necessity. The second is the spirit of service, manifested in an intelligent foresight of the needs of the situation. We can not expect the command and staff to give us the free hand in the execution of details that we rightly believe we should have, unless we execute these details without being told to do so. If the staff are convinced that the engineers will do what is needful without orders, the chances are strong that they will not worry the engineers with orders. But it takes time for this conviction to establish itself in their minds. In the meantime, if they are very inexperienced, the conviction may form that the engineers have nothing to do, and will form a nice little reserve against the

emergencies of battle, to be so placed that they can not, under any circumstances, do anything useful; or, if the staff be more experienced, the conviction may form that the engineers will overlook some vital task, with the consequence that definite and detailed orders fritter away the engineer strength in ill-developed dispositions. It is essential, therefore, that the engineer in charge prepare his programme and present it to the staff before the latter have gotten to the consideration of the disposition to be made of the engineer troops. This procedure applies to the major commanding the engineer companies with a brigade and to the captain commanding the engineer company or platoons attached to a regiment, as well as to the colonel commanding the engineer regiment. If any of them sit around and wait for orders, they cannot complain if they get them. But if these officers promptly present for approval their plan for the utilization of their troops, the chances are strong that it will be approved in toto, and even stronger that any instructions modifying the plan will be given in very general terms. It may be helpful to view the situation from the other side. Supposing an engineer officer has an infantry escort assigned his unit for a guard in the execution of a detached mission. The engineer will much prefer that the commander of the escort say "I propose to do thus and so" than that the commander say "Here I am, what do you want me to do?"

In only one respect do I differ from the author of the article in any degree, and that is in the attention to be given to the infantry training of engineers. By this I mean combat training, not infantry close-order drill. As the author points out, the time may and does come, with the exhaustion of the infantry, when the engineers must go in. That may be the time when the enemy is also near the point of exhaustion, and when a relatively small body of troops, skilled in offensive combat, may reap the results of the large losses that have been incurred. Unless the engineers are trained, and very thoroughly trained, they cannot be used in the exploitation of the attack. The opportunity to so use them will be rare; it may never come; but the chance of its coming is, in my opinion, worth every effort made in preparing for it. Such preparation is not lost time in any event; on the contrary it is very well spent time, for it teaches the men to handle themselves and avoid unnecessary losses in their regular duties in the zone of fire. It teaches them the theory of the organization of a defensive position

in a much sounder way than if such organization is approached from an engineering standpoint merely.

The organization of a defensive position is of course one of the most vital duties of the engineers. The responsible infantry commanders will select the line, and will plan the organization. But the engineer detail with the tape, who quickly and intelligently stake out the line, and get the details of flanking fire properly adjusted, are not unessential elements of the success of the undertaking.

The occasion arises, moreover, in which the engineers must lay out the organization of the defensive position. A brigade commander, in action, is not a gentleman of leisure. He may have time merely to make a pencil jab at the map and tell his major of engineers: "Organize a line of resistance here." Thorough instruction in the organization of a position, *in the manner that meets the approval of the infantry,* is therefore essential to the engineers.

It is an established principle that the senior engineer on duty with a unit is the technical adviser of the commander. Some engineer officers construe this proper principle as a mandate that the unit commander should seek the advice of the engineer in all matters in which engineering is concerned; which is to say in all military operations. Nothing is further from correct. The advice proper from the engineer is that he has made such disposition of his material and troops that such and such a bridge will be built by such and such a time, or that he must have so many trucks in order to execute the work specified to be done. The advice most valuable of all is that the necessary roads have been opened to motor traffic, and that water points have been installed for the supply of the forward troops.

Col. Francis B. Wilby, Engineers (by letter).

The above article on the Relation of the Division Engineer to the Artillery and Infantry is of special interest to the engineer officer, but should be of nearly as much value to officers of other arms which require the services of engineer troops, and who therefore should have some idea of the powers and limitations of the engineer personnel with a division.

Before the war the relation of the engineer to the other arms had been only briefly touched upon in our various service publica-

tions, with the consequence that few staff officers, or division engineers even, had a clear idea of the functions of the engineer regiment with a division.

I believe that the above article brings out the two most important points bearing on the successful use of the engineers with a division. These two points are:

1st. The *spirit of service* to the division, for the Division Engineer and all of the personnel of the engineer regiment. This, I believe, is the most important single factor affecting the success of any divisional engineer regiment, for no matter how well disciplined, trained, or perfected it may be as an individual organization, unless it is constantly helping the other troops in the division, whether in battle, on the march, or in camp, and unless every other organization in the division is ready to back it against any other engineer regiment in the army, then it has not gained the confidence of its division and it has failed as a divisional engineer regiment.

2nd. The necessity of avoiding in operation orders the requirement that "the engineer regiment will be in reserve," and the use in such orders, whenever possible, of some such general phrase as, "the Engineers will support the attack." This apparently minor point is, I believe, of great importance in that it squarely puts it up to the Division Engineer to see that his troops are *where* they are needed, *when* they are needed, and if the engineers fail, the responsibility is where it belongs namely, on the Division Engineer. In elaborating on the detailed duties of engineers under various situations, it is believed the article overstresses the *supply* function of divisional engineers. The Engineer Service is by no means a mere service of supply, in spite of the fact that many staff officers like to consider it as such. Its supply functions are entirely subordinate to its operating functions, and should never be permitted to overshadow them. If any engineer officer thinks that his duty is done when he has furnished supplies to the other arms of the service, he is sadly mistaken, for in reality his duty is only begun. The term "supply service" when applied to the Engineer Service is as much a misnomer as it is when applied to the Medical or Signal services, and should be discouraged as much as possible.

The impression is gained from the above article that there is a fixed distribution of the engineer troops with a division, which applies at all times and under all conditions: to each brigade of infantry, a battalion of engineers less one company, giving one engineer company to each infantry regiment, and assigning one engi-

neer company to the artillery brigade, and the remaining company to the division dump. It is not quite clear from the article as to who exercises command over the engineer troops thus distributed, but apparently the Division Engineer would command one company at the division dump, each infantry colonel would command the engineer company assigned to his regiment, and the artillery brigadier would command the company assigned to his brigade.

Such an arrangement has, to my mind, several serious defects. In the first place, this distribution of engineers will not meet the needs of all situations, and infantry and artillery commanders should not be led to believe that they may expect this proportion of engineer troops to be assigned to their command under all circumstances. On the contrary, there is no nominal distribution of engineer troops, as their distribution will depend entirely upon the condition to be met, and all must be available for concentration, if necessary, where they are most needed.

In the second place, the policy of turning each infantry regiment into a miniature division with auxiliary troops from all arms attached, is believed to be unwise and leading to an unnecessary and possibly disastrous dissemination of officers. Engineer troops when performing engineer work in the division area, should be under the command of the Division Engineer, acting under the orders of the Division Commander. This may at times seem a little inconvenient for certain infantry or artillery commanders when the engineers are operating in their areas, but with proper cooperation this should cause less trouble than if the engineers are placed under the command of the infantry or artillery officer, who in most cases is not familiar with the duties of engineers, and who before long will probably divert them from their proper use thus causing endless trouble if the Division Engineer tries to get them back on to their proper job.

It is believed that if the infantry or artillery brigade or regimental commanders are to command engineers, then a proper quota of engineer troops should be permanently assigned to the infantry or artillery brigade or regiment, in order to avoid the almost certain conflict of authority which will occur if companies from the divisional engineer regiment are attached for orders to the various infantry or artillery organizations of the division.

Under the heading "*Preparation of Sector for Defense,*" appear certain quotations from the new provisional Infantry Drill Regulations. It is hoped that before these regulations are approv-

ed, some of the passages quoted will be changed, as they certainly advance some of the most surprising theories. For instance, "The Brigade Commander . . . allots the necessary engineer personnel and material to the different positions." Possibly these new regulations contemplate an organization with brigade engineers, but, until such are provided, it is not seen how a Brigade Commander can allot troops and materials which are not at his disposal.

The author in discussing this same subject says, "A line laid down actually on the ground to connect up combat groups which have been determined upon as vital by the Battalion and Regimental Commanders." It has been my experience that the lowest commanding officer who has ever shown any interest in picking out the main defensive position has been the Brigade Commander. It will be the exception, I believe, if infantry regimental commanders have anything to do with selecting the main line of resistance of the battle position, and certainly battalion commanders will never be called on to select this line.

The impression is gained after reading the paragraphs on the "*Preparation of Sector for Defense,*" that an engineer officer does not have to know anything at all about the principles of the organization of the ground for the defense, but that all he has to do is take the line as laid out by the infantry commanders, and "get a line of wire in front of it." This impression I do not believe was intended to be conveyed by the author, for any division engineer who is not prepared to go out alone, or with only his engineer staff, and select a defensive position, and lay it out in all its details, so that it will be satisfactory to the infantry commanders, is going to be seriously embarrassed, if not actually a failure in one of his principal duties as Division Engineer. It is all very well to lay it down in regulations that the Brigade Commanders or others are to select these defensive positions, but nine times out of ten the Division Engineer is going to be called on to do it, and he must be prepared.

In the paragraphs covering the "*Preparation for Offense,*" and time spent "*In Training Area,*" the duties of engineers in various situations are well described, and in such a way as to bring out the importance of a real cooperation between the different arms of the service, which, in the end, is the only way in which any arm may hope to win success. The article as a whole is the best exposition of its subject which we have to date, and should be studied by officers of other arms, as well as by all engineer officers.

Final discussion by Col. George R. Spalding (by letter).

The paper as printed is a rather incomplete stenographic report of an informal talk given to the officers at the Center of Artillery Studies at Trier, Germany.

Good fortune made it possible for me to grow up with a National Army Engineer Regiment and to serve with that unit in more or less ''noisy'' sectors on the British front and for a short period in an offensive on the American front. Later I had opportunity to observe the work of a large number of divisional regiments in offensive operations and still later in training areas and in occupied territory. It was also my good fortune to talk with a number of Division Commanders, and those who had been Division Commanders, about their engineers and it was mighty pleasing to one who has the best interests of the engineers at heart to hear the fine words of praise so honestly and generously given in a great majority of cases. There were as many ''best engineer regiments in France'' as there were ''best Divisions'' in France. No two of these ''best regiments'' operated exactly alike. Different men organize differently. One should not, therefore, lay down a hard and fast rule for organization. Even type organizations are dangerous, as without the same personnel and the same, *exactly same,* training and spirit the type would fail, perhaps.

In my talk I said with great care, for fear of being misunderstood, that by assigning a Battalion less one company to each Brigade, a company to each Infantry Regiment and one company to the Artillery, I did not mean that the regiment was broken up in any such fashion but I did mean that the Battalion Commanders and Company Commanders had always the job of looking after their particular units. I might have added—for the sake of clearness—the old familiar phrase ''in addition to their other duties.'' The assignment, it will be understood, was not made in the G-3 order, indeed, when I could avoid it, no assignment of engineer troops was made by G-3 order.

If a Brigade had a mission to perform, the Major of the Battalion assigned that brigade learned it at once by phone or otherwise from the Brigade and he and the Brigade Staff figured out the engineering needs. The C. O. of the engineer regiment saw to it that as far as possible the Major had the men and materials to meet these needs. Under no stretch of imagination was the regimental commander left with but one company. He had all the

companies. His was the responsibility to see that all the engineering work required was done and this tentative assignment helped him do it, because it kept him advised as to needs.

Summing up, it seems to me that the lessons of the war teach the engineers to (*a*) develop the "Spirit of Service" to other arms; (*b*) quit criticising, and (*c*) so foresee and plan and do that the orders they receive shall be in all essential particulars *drawn* up by themselves.

THE FIRST SIX WEEKS ON THE WESTERN FRONT.[1]

By

Col. C. L. Hall,

Engineers, U. S. A.; Assoc. M. Am. Soc. C. E.

The German General Staff was well aware that war is a continuance of politics. What they did not know is that there is a good deal of politics to war. And what they particularly forgot is that, while one's military means must be suited to the carrying out of one's political ends, those ends must themselves be not only militarily but politically practicable.

I will not discuss the political manœuvres which preceded the commencement of the Great War. They are hardly pertinent in a purely military discussion. A statement of the political situation, as it existed on August 1, 1914, is necessary for an understanding of the *military* situation.

1. There were at war, or certain to go to war, on August 1, 1914, on the one hand Germany and Austria-Hungary, on the other France, Russia, and Serbia.

2. The attitudes of Italy and Rumania were doubtful, and were likely to be determined by the course of the campaign.

3. The Belgians and Swiss wished for neutrality. The latter would certainly attack any invader. The former would probably resist German invasion. They might or might not resist entente pressure, but such pressure would never be brought to bear until after Great Britain's entry into the war.

[[1]This article was prepared originally in the form of two lectures to be delivered at the Army Engineer School, Camp A. A. Humphreys, Virginia. These lectures formed a part of the course in Military Art, a course designed to indicate to the student officers the Leavenworth methods of teaching the subject. The paper is intended as a study of the method of applying the Leavenworth or "Estimate of the Situation" system to the discussion of past events of intense interest. It suffers from the lack of authentic reports, but such a disadvantage will be experienced by all students of the Great War for at least one generation. The article covers the campaign on the Western Front down to and including the First Battle of the Marne.—The Author.]

4. The eventual entry of Great Britain into the war seemed certain to the German military party. Their direct military participation was thought, however, to be extremely limited, both actually and prospectively.

5. The politicians had successfully convinced all the combatant peoples that they were fighting a holy war in self-defense. The exceptions were:

(*a*) The Poles, excluding the Austrian Poles;
(*b*) The Finns;
(*c*) The Czecho-Slovaks;
(*d*) The Bosnians and Austrian Italians;
(*e*) The Alsace-Lorrainers.

These exceptions had some little influence on the German choice of plan.

The doctrines which actuated the staff in this choice can be found in almost any of the authoritative German books. It will be well, however, to quote a few phrases from von der Goltz's "Conduct of War."

"Just as we can not think of armed conflict without decisive engagements, so it is nowadays no longer possible to imagine wars, in which states which have entered into a quarrel, do not go forth with their full strength, and do not contemplate an overthrow of the enemy;

"To wage war from a mere love of fighting, or from a passion for plunder and conquest, is now vetoed by advancing civilization, since the state of civilization of the nations has become such that it suffers by every war. The victor, therefore, strives to compel his enemy to accept the desired terms of Peace as rapidly as possible. But as this is only possible when one of the parties has lost all prospect of success, here again is an argument for the necessity of defeat or destruction."

The political situation compelled the Germans to fight on two fronts. On the western front they necessarily would have to fight alone. On the eastern front they would have the assistance of Austria-Hungary, but that nation also had to guard two other fronts:

(*a*) The southeastern against Serbia;
(*b*) The southwestern against Italy.

On all three of these fronts the reservists living on the frontiers were likely to be tainted with treason, and on the southeastern front they were certain to be. Therefore, they had to be moved to other fronts to fight. This made necessary a slow mobilization of Austria-Hungary.

The Germans knew that the Austro-Hungarian Army was not in

first-class condition. They believed, and rightly so, that it would improve by direct association with the German High Command, but such association could not commence in advance of active hostilities. For these two reasons the potential value of the army of the dual monarchy was regarded as greater than its initial value.

The Germans knew well that they could not win on both fronts simultaneously. They had to defend on one and attack on the other. The main decision was, therefore, whether to open by a Russian or a French offensive. The decision was, doubtless, taken many years ago, but such is the flexibility of their staff work, that it could have been revised at the last minute if necessary. We will, therefore, treat it as if it had been made on the night of July 31st.

The advantages of a Russian offensive were:

(*a*) It might result in an uprising in the Russian border provinces, all of whom were imperfectly attached to Russia, and in some of which pro-Germans were the leading citizens.

(*b*) It might lead to the destruction of a portion of the Russian first-line armies, thereby eliminating a large proportion of the pitifully limited Russian officer-class.

(*c*) If entirely successful it would result in an occupation of the grain-producing regions of Southeast Russia, and make Rumania an ally.

(*d*) It might cause a revolution and place in power an element, which, if not pro-German, was anti-Panslav, and hence anti-war, thereby causing peace on the Eastern front.

The disadvantages were:

(*a*) The Russian zone of concentration and barrier-fortresses was so far to the rear that a long march over poor roads would be necessary to reach them.

(*b*) The conquest of Russia was an enormously difficult task. A skillful withdrawal of defeated troops could prolong a campaign indefinitely. No really definite campaign of victory could be accomplished in the east unless the entire resources of the German State could be put into the task, something impossible as long as the French front was alive.

(*c*) The military value of the Austro-Hungarian Army was not at its maximum at the commencement of hostilities, and, as it could be used only on that front, its utilization might advantageously be postponed.

The advantages of a western campaign were:

(*a*) If decisive it would eliminate a whole region from the theatre

of operations, and give security to Germany in its campaign against Russia.

(*b*) It would prevent British military participation in the war.

(*c*) It might furnish, by way of indemnities, invaluable financial sinews of war.

(*d*) Its moral effect on Italy would be striking.

(*e*) Greatest of all, one front would be on enemy soil.

The disadvantages were:

(*a*) While France would surely enter the war anyway, the effect on the morale of the French lower classes of putting them in the attitude of defenders of their own soil, and not of mere aggressive allies of Russia, would be enormous.

(*b*) If checked, the growing power of Russia would force the resumption of a defensive attitude, and would therefore prolong the war in a spot where British military participation and supply of material would be easiest.

(*c*) The atrocities inseparable from the German plan of war would be committed where they would have the maximum effect on neutral opinion.

(*d*) Unless the invasion of France was preceded by direct French aggression (something the French politicians skillfully prevented), the "imponderabilia" would be against Germany.

All these advantages and disadvantages were doubtless weighed by the Staff. But they came to the conclusion that they could put France absolutely hors de combat in a few weeks, but could not do this to Russia, and, therefore, ought to open the campaign in the west.

It is generally believed that this campaign was almost successful, and the risk was, on the whole, justifiable. The principal error was undoubtedly the poor work of the peace-time intelligence service on the eastern front, which made the Germans think they had more time to counter the Russian offensive than they actually had; nevertheless, considering the man-power at the disposal of the two belligerents, it may well be doubted if the scheme had any real chance of complete success without a French Revolution. How much chance there was of this, is for the politicians and not the soldier to say. There were not many signs of it in 1914.

Having decided on a first-class offensive in the west, the Germans had practically three sub-choices:

(*a*) Attack via Switzerland;
(*b*) Attack over the political frontier (Franco-German);
(*c*) Attack via Belgium.

The fourth alternative, an enveloping movement on both flanks, required too great forces to be feasible.

It is not probable that much time was wasted in thinking of a Swiss invasion. A vigorous nation, largely of Germanic blood, would thereby be converted into an active and dangerous enemy. Moreover, even if successful, it would be a threat at an unimportant part of France; and no threat at all at the French Army.

Fig. 1.

Before considering the military reasons which led to the invasion of Belgium, we should examine the topographic nature of the frontier. At the extreme south was the Trouée de Belfort. This pass favored the French and made the retention of upper Alsace by German forces of reasonable size impossible. The route, however, led nowhere in particular and could be given up without much loss. No considerable advance could be made without seizing the Vosges defenses on the flank.

Just north of Belfort lay the Vosges Mountains. The frontier followed the crest, and the barrier was terminated by the highly fortified

post of Metz, not far from the Luxemburg frontier. The mountains were bad enough, but just behind them lay the so-called barrier forts, Belfort-Epinal-Toul-Verdun, all strong points, which would require great efforts to reduce. A German attack over the mountains would thus give cramped space to the attack, and many benefits to the defense.

Luxemburg and the Belgian Ardennes did not offer much as a theatre of operations, but north of these lie the valley of the Meuse and the Belgian plain, highroads of invasion since the earliest days. These were barred by the two Belgian river fortresses of Liège and Namur, and the French fort of Maubeuge. The two former were built according to the best Brialmont principles. Neither was of any use without a brave and trained garrison, and the curtain forts of both had too little overhead cover to resist modern howitzers. Maubeuge was a partially finished affair and betrayed in its construction the indecisions and delays incident to parliamentary government on military appropriations.

The railway lines through Luxemburg and Belgium were admirably adapted for the support of an army, and the roads were excellent. A successful invasion would immediately put at German mercy a most productive portion of France. It would also insure the exploitation of the Briey basin, and safeguard the very valuable deposits and factories in South Luxemburg.

Regarding the military nature of the Vosges frontier, the strength of the curtain and the cramped space for deployment, it is true that a direct invasion of France afforded little hope of success. When, therefore, a French invasion was decided upon, the invasion of Belgium became, from a military point of view, a necessary corollary.

The French were well aware that a German invasion of Belgium was probable, but they greatly underestimated both its force and its purpose. Their idea was that it was a mere covering force for the left flank, and the main line of operations would pass through Metz.

In analyzing the French reasoning in detail, we are met with the difficulty that no French despatches have ever been published, and that Marshal Joffre has recently testified that there was no real plan. About all we can do is to point out the known facts, and suggest the probable reasons.

At the commencement of the war the German Army consisted of 25 corps. All were in first-class shape, and all except the Guards were recruited from definite territorial areas. The frontier corps contained numerous units from areas outside their region, but they could be just as good Hanoverians in Metz as anywhere else. About the only ele-

ment distributed around, and so to speak diluted, was the Alsatians. All the troops were commanded by leaders in whom they had confidence. The few Princes for whom high positions had to be found were provided with efficient staff officers. Equipment was excellent.

The Belgian Army contained about 60,000 men; the military value of the machine was not regarded highly, either at Berlin or Paris. Theoretically it could be expanded to 350,000, but the German invasion prevented most of the expansion taking place. The leaders were of unknown quality, and only one made any outstanding reputation beyond the limits of his own country. Equipment was inferior to that of either the French or German forces.

The French Army consisted of 21 corps, in France, and one in Algeria. Consequently, if the French system had been in as good working order as the German, having regard to the German army corps which could not be withdrawn from the Russian frontier, France should have been able to assemble approximately the same forces at the opening of the campaign as her enemy, and owing to the distances to be covered by train in effecting this assembly, the French corps should have been in line before their foes. They were not.

After hostilities commenced, the armies of all three states needed time for the three indispensable preliminaries of modern war, mobilization, assembly and concentration. Mobilization is the act of rendering mobile the armed forces of the state. It embraces—

(*a*) The summoning to the colors of the reserve establishment of the active army, and their arrival and equipment;
(*b*) The summoning to the colors, arrival, equipment and organization of the second and third line units;
(*c*) The transfer to third line units of untrained recruits. As the military year in Europe begins in October, this step was unnecessary in 1914, all recruits having had 10 months' training;
(*d*) The subordination of all the machinery of transport, railways, trucks, horses and vehicles to the needs of the army.
(*e*) The distribution and forwarding of enormous quantities of military supplies.

It will be seen that mobilization entirely suspends the economic life of the country, and arouses national feelings which make war inevitable. Only the merest preliminaries, such as recall of officers and men on leave, can be taken in secrecy. It does not, however, involve a single member of the active army leaving his station.

The assembly is the movement of these troops to billets in the zone of assembly. This zone is normally as near to the frontier as is deemed safe. The assembly is protected by the frontier corps, whose peace

strength is generally greater than the others. These corps are posted as outposts. They also protect the frontier fortresses. If one set of frontier corps defeats the other set, the advance is quickly checked by these fortresses, whose garrisons are strong enough to enable them to hold out until the assembly is completed.

Concentration is the closing in for battle of the various armies from the regions in which they were assembled. It is the last step before the shock of the first great battle.

Thus, when a German corps received its reservists and war-strength transportation it was mobilized, when it moved by many trains to billets in the Saar Valley it was assembled, when it marched by a few roads past Metz and towards the enemy it was concentrated.

As the French had but one active front, their frontier corps were stronger than the German. Consequently they were in control of their frontier until concentration was completed. On the other hand the Belgian frontier troops were insignificant in size. Therefore the frontier corps in Rhenish Prussia had control of the situation there.

The first definite military steps were taken by Belgium and Holland on July 31st. The former ordered a partial, the latter a complete, mobilization on that day. The Dutch troops can be dismissed from consideration, as Holland managed to maintain its neutrality. The troops were very useful in preventing accidental violations of territory and in interning refugees. Thereby all excuse for an invasion of Holland was prevented. Belgian complete mobilization was not ordered until the night of August 2nd, but it seems to have been in full swing when it was ordered.

French and German general mobilization were both ordered late on the afternoon of Saturday, August 1st. Prior to that time, military preparations, increasingly definite, had been taken. The reservists of frontier corps who lived on the frontiers had been summoned, horses had been requisitioned, etc. The French had probably started first, and their first-line corps were probably ready before the Germans. Insufficient preparations had been made for the mobilization of second-line troops, and the Germans must have had nearly twice as many men under arms when the first shots were fired.

The first active step was taken by the Germans. On August 2nd, a stream of soldiers in motor cars poured over the Luxemburg frontier and seized the city railway station. The corps at Trêves promptly reinforced these men, and most of the Grand Duchy was thereby added to the zone of assembly.

That same night an ultimatum was sent to Belgium, which was rejected, and the morning of August 4th German troops crossed the

frontier. The troops were without their reservists, who followed and joined them by train. The first movement was to envelop Liège by crossing the Meuse at Visé. Serious contact was gained here and some resistance encountered.

The garrison of Liège was about 25,000 men under Leman. It was mostly placed in the various forts around the city. An attempt was made to carry the forts by storm, but unsuccessfully, on the night of August 5th. Next day the town was taken but not all of the forts. The Belgian troops succeeded in getting out, leaving 250 men in each fort held. This stopped the use of the main Aix-la-Chapelle-Liège Railway line. By August 10th siege artillery had been brought up. The latter had a longer range than the fort guns and proceeded to knock the forts to pieces. The last one surrendered on August 18th.

In the meantime on August 12th, sharp encounters took place between Germans and Belgians on the left bank of the Meuse, and the French and German Advance Cavalry met in the Belgian Ardennes. The Belgian Army fell back in pretty fair order, and by the 15th held the general line Wavre-Tirlemont-Diest-River Neith.

So far the Belgian resistance had been based on hope of Anglo-French assistance. This assistance did not materialize until too late. It is necessary to understand the reasons.

As already stated, the French thought the attack through Belgium would not amount to much. They feared that it was a feint, or that Germany would withdraw under British threats. It was not until August 7th that they appreciated the seriousness of the invading army, and five days later that they gained contact in Belgium. During the interval they became committed to rather serious enterprises elsewhere.

As I have said before, the French reasoning cannot be obtained from any published literature. It must be deduced by analysis. Apparently it was about the same as that of Napoleon III in 1870. Namely, their superior forces at the outset would enable them, by a vigorous thrust at the enemy's flank in Alsace-Lorraine, to overwhelm the German frontier lines, interfere with the German assembly, and establish positions on German territory from which they could not subsequently be dislodged. They were also undoubtedly actuated by the natural political desire of reoccupying the lost provinces.

The French forces assigned to the offensive along the line Pont-a-Mousson-Belfort consisted of nine corps. Six of these were designed to penetrate between Metz and Strasbourg, three for the attack in the Trouée de Belfort. Fighting began August 4th. On August 8th, a

French Corps seized Altkirch and Mulhausen, but on the 11th they were compelled to evacuate the latter place. During this time, however, they seized some of the southern crests of the Vosges, which they never did lose. The Alsatian offensive was resumed on August 14th, and on August 18th the Army near Pont-a-Mousson (de Castelnau's) was completely assembled. On that date fighting became general.

The situation was as follows:

Entente:	Belgians, on line Wavre-River Neith. British, marching on Mons. French Army of Reserve Divisions, forming on left of British, but so far unorganized. French Advance Cavalry, near Namur. 13 Corps, on line Charleroi-Verdun. 9 Corps on Frontier, divided by the higher Vosges crests into one army of 6 corps in north and one of 3 in south.
German 1st Army (von Kluck):	Preparing to occupy Brussels and mask Antwerp. One column marching on Tournai and Lille. Another body marching on Mons.
2nd Army (von Bülow):	Investing Namur and marching on Charleroi and Maubeuge.
3rd Army (von Hausen):	Marching through Malmedy on Givet.
4th Army (Duke of Wurtemburg):	Marching through the Ardennes on Sedan.
5th Army (Crown Prince):	Marching from Trêves and Luxemburg via Arlon on Longwy and eventually Verdun.
6th Army (Crown Prince of Bavaria):	Defending Metz.
7th Army (von Heeringen):	Marching from Strasbourg on Lunéville.

A few reserve divisions, holding upper Alsace.

It can thus be seen that each army was guarding its left flank, and preparing to strike with its right. In a general way, it resembles the situation at Stone River. The strength of the two forces was not very different. Success was to come to the one who—

(*a*) Took the best ground as a theatre of attack;
(*b*) Took the most easily defensible ground as a theatre of defense;
(*c*) Had the better high command;
(*d*) Struck where the consequences of success would be the greatest.

It must be realized that on August 7th the French saw that something must be done for the Belgians. Consequently, reinforcements were diverted from the extreme right to the extreme left. Therefore, their original plan of operations was never carried out.

The great Battle of the Frontiers, the greatest battle up to that time in history, began on August 18th and ended on August 24th.

It may be conveniently divided as follows:

(*a*) Battle of Wavre, or 2nd Battle of Waterloo, between the 1st Army and the Belgians.
(*b*) Battle of Mons, between the 1st Army and the British.
(*c*) Capture of Namur by 2nd Army.
(*d*) Battle of Charleroi-Longwy, between 2nd, 3rd, 4th, and 5th German Armies and the French.
(*e*) Battle of Morhange, between 6th Army and de Castelnau.
(*f*) Invasion of Alsace.

The exhausted French Cavalry, who had ridden all through Belgium, played practically no part in the Battle of Wavre. The Belgian Army contracted its front, and endeavored to fight a series of rear guard actions in front of Brussels. They were thoroughly and soundly defeated, and driven through Tirlemont and Louvain on Malines. This uncovered Brussels, which was occupied on August 20th. The Belgian Army made a kind of sortie on August 23rd, which had some initial success, and was made the excuse for the sack of Louvain. A German Corps recaptured Alost, Termonde and Malines and invested Antwerp. Belgian military participation was temporarily suspended.

On August 23rd the British forces of less than 50,000 men at Mons were attacked and driven back on the line Bivay-Maubeuge. It is probable that they could have held out longer, but the defeats further along to the south made their position untenable.

At Namur, the Belgians had a force of about 30,000 men. Its commander was irresolute and did not realize that his garrisons were no particular good to the entente as mobile soldiers, and that their best function was to die at their posts and delay the advance by holding on for the longest possible time to the vital road and railway junctions of Namur. He heard vaguely of a successful German attack towards Charleroi, and evacuated his field divisions leaving only his fortress garrisons. The forts were bombarded the afternoon of the 22nd and all day the 23rd, and were then unceremoniously abandoned.

On August 20th, the French passed from the defensive in the region of Charleroi. This affair resembles the typical defensive-offen-

sive of text books, being an endeavor to throw the 2nd and 3rd Armies in confusion by a vigorous attack before they had been completely deployed. Its eventual success was highly improbable from the start, for, to win a real victory, support would have to come from the combination of British Troops and French Reserve divisions near Mons. As these latter were not yet in existence, and as the British forces were very small, nothing much could have been foreseen from the direct offensive, unless it resulted in a rout. The time had not yet come (if it ever did come) for the policy of "nibbling" and "attrition."

The direct data available on the Battle of Charleroi-Longwy is rather meagre. The 5th Army was investing Longwy, which was a very second-rate fortress. On its right was the 4th Army. The French attacked with great impetuosity on the 21st and were absolutely shattered. The German artillery and machine guns played havoc with them. In the meantime the 2nd and 3rd Armies had forced the passage of the Meuse between Dinant and Namur. The 2nd German Army attacked the 5th French Army at Charleroi and after an engagement on the afternoon of the 22nd and morning of the 23rd, captured Charleroi, and the crossings of the Sambre. The 3rd Army attacked the French at Dinant and captured that place. The whole French left wing had to retreat.

On the right de Castelnau moved forward on August 19th and started on Saarburg. On August 20th a general battle occurred on the line Morhange-Conthil. The same style of reckless and gallant attack was pursued as at Longwy, and with the same results. One entire French corps was destroyed as a fighting body. De Castelnau retreated with very great skill and took up a position on the Couronné de Nancy, which he held against a German attack on August 22nd. The 7th German Army moved forward and on August 23rd reached Lunéville. The troops operating against Mulhausen succeeded in taking the town, but the general situation prevented any further advance.

On August 25th the situation, therefore, was as follows:

On the extreme (French) right the French had won a sterile victory and could move no farther, though Belfort was certainly made entirely secure.

From there north to Pont-a-Mousson the French attack had failed, but the German advance had been halted. It was a draw.

Over the whole left flank the allied forces had been definitely defeated, and were in retreat. The Battle of the Frontiers had been won by the Germans.

2nd Phase.

On the conclusion of the Battle of the Frontiers, the French Commander-in-Chief was forced to a strategic defensive. All he could do was to retire on his own base, shortening his own line of communication and lengthening his enemy's. In order to save France he would be compelled to delay the enemy's march as much as possible; and await a propitious moment for a vigorous counter-attack.

On August 28th, Mulhausen was abandoned and the French fell back to the region of Thann, where they were never seriously disturbed. The troops released by this withdrawal were sent to reinforce the garrison of Paris. In the meantime, the Army of Reserve Divisions, under d'Amade, the hero of Morocco, began to have some real existence and went to reinforce the French left.

The Germans made no alteration in their original plan. The great victories of the third week of August had heightened their morale and they all were firmly convinced of the wisdom of their initial plan of destroying the French Active Army as a fighting force.

Meanwhile, however, serious events were occurring in the East. The Russian frontier was defended on the German side by adequate fortresses, and there were four or five first-line corps on duty as frontier guards. These could cover the assembly, but were ineffectual against a serious attack. Nevertheless, pending the arrival of the troops from the Moscow region, the Austro-Hungarian forces should be able to keep the Russians in check. Their frontier forces were at least equal to the Russians in size and their mobilization ought to be quicker.

The German Staff had, however, grossly miscalculated the length of time required for the mobilization and assembly of the Russian Armies. By August 16th the latter had inflicted a serious reverse on a German corps. On the 21st, the Germans were again defeated, and the invasion of East Prussia began. It is true that the invading troops were subsequently, to all intents and purposes, destroyed at the Battle of Tannenberg (August 26th–September 1st), but such a victory was not procured without the diversion of Reserve Corps intended for France. Shortly afterwards the Russian Armies defeated the Austrian forces in Galicia. All these actions made it evident that troops would shortly have to be transferred from west to east. Therefore, a decisive victory in the west must be prompt. Any serious tactical check would cause so much delay that the campaign could not be pushed to a conclusion for lack of men. The strategy of the Marne

Campaign on both sides cannot be understood without a comprehension of this factor.

The German Troops pushed forward immediately after the great battle. All the Armies, from 1st to 5th, inclusive, were concerned in this march. The 5th Army in front of Longwy and Verdun was the pivot.

On the right von Kluck, with the 1st Army, was assigned the task of defeating the British Armies on the flank, and by driving them in on the centre outflank the whole French Army. As his Army held the marching flank, he had to move fastest. As the troops in his front were all professional soldiers, he had to fight hard. As he held the flank, he had to guard the whole German Army against danger from d'Amade's force in the north.

Von Kluck's first endeavor was to hem the British into Maubeuge. Thereby he might repeat von Moltke's performances after St. Privat and drive the British into a fortress destined eventually to fall. This was prevented by a further retreat to the general line Cambrai-Le Cateau-Landrecies. This position was prepared for defense. Nevertheless, in view of the menacing enveloping movement, a further retreat was ordered on Vermand-St. Quentin-Ribemont. Before this movement could be carried out a battle resulted (August 25th-26th), which caused severe losses to the British, and to some extent disorganized their retirement. This disorganization would have probably been more acute had it not been for some little pressure from d'Amade's Army on the left.

As a result of this victory German Cavalry and motor cyclists were able to burst out and make a series of raids on von Kluck's own right. There were enough second-line troops in d'Amade's Army to keep up some garrisons against this attack, and land communication between Antwerp and Paris was technically intact, but the German 1st Army flank was nevertheless secure as long as it kept Paris in front of it. The Army's march was directed on Senlis.

In the meantime Gallieni had been assigned to the governorship of Paris. He strongly intrenched the outworks and prepared to hold the town. This decision was to be carried out whatever the Germans did, and was based on three reasons—

(*a*) If the Germans attacked Paris, it would be so strong that considerable detachments must be made to carry the town. In that case the main German Armies would be weakened at the decisive moment;

(*b*) If the Germans left Paris on the flank it would furnish an

excellent point from which strong attacks on the German line of operations could be made;

(*c*) The political importance of Paris is so great that its abandonment for purely military reasons might be fatal to the French cause.

The decision was probably sound, though it involved the locking up of several French corps.

The French Armies on the Meuse fell back more or less in step with the British on the extreme left. The units were preserved intact. The material advantages continued to lie with the Germans, but there were no conclusive successes, except at the pivot, where the Crown Prince took Longwy on August 26th. The same day he inflicted a sharp defeat on the troops pivoting around Verdun and was able to surround it on both flanks. By September 1st its investment was almost complete. A tactical check to the Prussian guard corps at Guise (August 28th) had no real influence on the situation.

About the same time, or a little earlier, the Germans decided that the capture of the French pivot forts, Toul and Verdun, would be of great advantage to their arms. These points were important railway junctions as well as fortresses. Even an unsuccessful offensive against them would mobilize heavy French forces away from the strategic flank. A successful offensive would disorganize the whole retreat of the French centre.

To secure the capture of these forts it would be necessary, in order to evade a ruinous frontal attack, to first seize the Grand Couronné de Nancy. This is the range which guards the east bank of the Meuse River, and has probably been the site of more first-class battles than any other place in the world. Its defense was in charge of General de Castelnau, the same man who had recovered so well after the defeats at Morhange.

No accurate account of this most interesting battle can now be written. It was a defeat for the Germans and they had no interest in describing it. The French, moreover, were not too desirous of playing up their principal victorious general because of his political affiliations. Consequently about all that can be said is that the battle opened on the afternoon of August 31st, that it continued practically without interruption until the night of September 9th, when the general German retirement was ordered. No German advances of any importance were made, Toul and Verdun were never seriously threatened, and the German losses were terrific. The French officers with whom I have discussed this subject are all agreed that it was the Battle of the Couronné de Nancy which saved France. It needs no expert strate-

gist to see that no sort of follow-up blow could be made in the Champagne, if Toul and Verdun were carried, and the French right opened up.

On the other end of the line, during the first days of the Couronné de Nancy, equally important events were occurring. On the 2nd of September, the German High Command diverted von Kluck's march from southwest to southeast. Accordingly instead of continuing to move on Paris, von Kluck moved south and on the 4th crossed the Marne. He left but one corps as flank guard. That day Gallieni decided to strike against this exposed Army from his own position in Paris.

A great deal has been written on the question whether the flank attack was made too soon. But writers overlook the fact that the

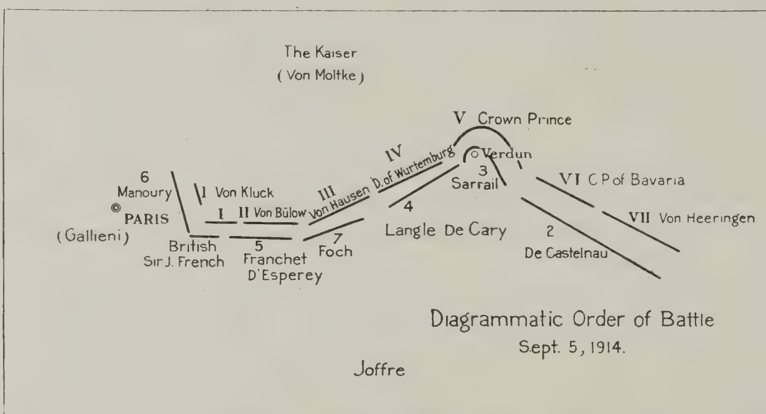


Fig. 2.

French Commander-in-Chief (Joffre) did not himself decide to resume the counter-offensive until the afternoon of the 5th, which was after the attack from Paris took place. Consequently, it is vain to argue whether the two strokes had not better have been simultaneous, for, if Gallieni had not started the affair, it might not have commenced until some days later; possibly then it would have been too late. We will have to wait until the insiders write their memoirs before we can settle this question.

The operations preliminary to the Battle of the Marne, which are generally known as the Battle of the Ourcq, commenced at noon on September 5, 1914. The general dispositions at that date were as shown in the sketch.

It will be seen that the German Armies were marching in line

between two fortresses, both in being. The one on the east, Verdun, was pretty thoroughly isolated; on the west Paris was open, contained troops in strength unknown to the Germans, and what was better, they were continually being increased.

The German forces were in fine feather, though getting physically tired. Of the French troops, the British contingent, and the 4th and 5th Armies, were pretty thoroughly exhausted. The 6th Army contained numerous fresh elements. The 7th Army was nearly all fresh, as it was largely composed of professional troops recalled from the colonies. It was this last Army which was destined to strike the hammer blow.

The 6th French Army opened the ball by a stroke against von Kluck's flank Corps. The stroke was successful, and the corps was driven back a short distance. Von Kluck immediately saw the danger and began withdrawing his southeastern elements, who were in front of troops he was not afraid of, to reinforce his own right. These troops were brought up all day on September 6th. During this day von Kluck's detached corps was being very hard pressed in the regions just north of Meaux. They gave ground stubbornly, and by nightfall reinforcements were reaching them. But at the same time the 6th French Army was being reinforced. Each side was straining every nerve to gain a battle under the walls of Paris. As for the British and the 5th French Army, they appear to have been so exhausted that a little cavalry was sufficient to contain them.

The Battle along this line continued all day the 7th and the 8th of September. By the close of the latter day the only serious French advance had been in the centre. This had been completely checked, and the growing strength of the German wings made a complete disaster not at all impossible.

On the 9th the situation brightened slightly for the French, because the British began to recover and in their turn to press on von Kluck's flank. The line in the Meaux region began to resemble a great figure S reversed, where everybody was outflanking everyone else. Nevertheless, von Kluck could still give way somewhat before the British and yet defeat Manoury. But that night the general German retirement was ordered. A victory in another place had saved Paris.

The movement of von Kluck's left wing required to meet Manoury's attack made it necessary for the 2nd German Army to extend itself and take over a considerable amount of ground. This thinned

their line, especially on their own left, which was occupied by the Guards corps. At the same time the retirement of the 1st Army's forces required the right of the 2nd Army to withdraw. Committed as they were to aggressive action this left the 3rd Army as the one striking force available, and accordingly to it was committed the general attack of September 6th. Von Hausen's own dispositions for this attack are somewhat complex; but with the 2nd Army edging away from him, a concentration for attack, or even a successful attack without concentration, would be almost sure to make gaps in his line; as we shall see those gaps occurred. The gradual extension of one's units to a flank combined with an attack is a manœuvre which only a very unusual general can handle; and von Hausen, though a fairly well-known ante-bellum tactician, seems to have been a most ordinary leader.

But in addition to the German attack there was another attack scheduled for September 6th. Von Kluck's flank march, and Gallieni's bold decision had become known to Joffre, and he decided that the time had come for a counter-attack. On the night of September 5th he issued a battle order which was less a tactical order than an appeal to patriotism. The Battle of the Marne was to begin in earnest.

The brunt of the battle was to fall on the 5th (Franchet d'Esperey's) Army. These troops were pretty well exhausted, but a little time had been given them to refit. Moreover, the troops in their front, the 1st and 2nd German Armies, were very tired from their long marches, and their lines of communication had become so long as to endanger adequate supply. For these reasons Joffre decided that while maintaining a defensive on his right and centre, a bold stroke on his left might, in combination with Manoury's battle of the Ourcq, cut off most of two German Armies.

Therefore, on the morning of September 6th, two first-class engagements were in progress. Along the lower reaches of the Marne Franchet d'Esperey was assailing von Bülow. In the vicinity of La Fère Champenoise, von Hausen was attacking Foch.

Both manœuvres were at first successful. But in the meantime, as we have already seen, the Battle of the Ourcq was developing in a German sense. Moreover, von Bülow's threatened units were falling back in good order, without giving away any essential territory. At the same time Foch's right was being hardly pressed. It began to look as if Joffre's scheme would fail, while von Hausen might pierce the centre and thus force the whole strategical flank of the French Army away from the main body towards the Seine. This would

certainly isolate de Castelnau and Sarrail and bring about a grand style Sedan.

All day the 6th, 7th and 8th, the struggle raged. From the walls of Paris to Lunéville a tremendous battle of the Nations was in progress. But by the night of the 8th von Hausen had overreached himself. Concentrating as many troops as he could on his own left in order to threaten Foch's right, he thereby weakened his own right. He might have escaped had he been opposed by a second-rate man. But in his front the Army was led by the future Generalissimo of the Entente. Foch's intelligence service was none too good, but he saw that von Hausen's right flank was thin. Moreover, the news from the front of Paris was more and more disquieting. Something had to be done, and done quickly. Gathering all available forces, Foch, on the 9th of September, struck at von Hausen's weakened right.

The blow was entirely successful. While it did not develop its full effect until late afternoon, that very fact was of assistance to Foch, for by that time practically all the available German reserves were pressing the issue in the east. Nothing could be done to stop Foch.

The effect of the blow was electrical. The withdrawal of von Kluck and von Bülow had left von Hausen and the Duke of Wurttemburg in a kind of pocket. Foch's advance threatened the communications of the 3rd Army, and might drive the whole German centre towards Longwy and away from the marching flank. The 3rd Army had to retreat and retreat quickly.

That night, September 9th-10th, the German High Command decided on a general retirement. It was possible to fight it out a little longer, and even to make of the Marne a mere check, had men still been available; but the Russian campaign was opening and the crowds of refugees from East Prussia indicated only too well that the offensive in the west must be finished. Von Hindenburg needed all the reserves he could get.

The retreat continued all day the 10th, 11th and 12th. The enemy forces were in good order and the rear-guard actions were on the whole successful. By nightfall on the 13th, the Great Army from Verdun to the Aisne was in its prepared positions. For three more days Joffre made frantic efforts to turn the Germans out before their line stabilized. But the effort was in vain. The few elements which crossed the dead line were hurled back with bloody loss. By nightfall on the 16th, trench warfare was general from the Oise to the Swiss

Border. The line had reached a position from which it hardly varied until the victorious Allied counter-offensive of 1918.

The immediate and proximate cause of the German failure was doubtless the inadequacy of General von Hausen. But it is begging the issue to assign one error as the reason for the failure of a grand plan. The Germans had received some strokes of luck upon which they should never have counted, such as the strength employed by the French in the fruitless invasion of Upper Alsace. The truth is that the German plan of forcing a separate peace with France before Russia could become an active threat was doomed from the start unless every link in their chain was perfect. But such perfection does not occur in human material; some allowance must always be made for an inadequate commander; there must be some factor of safety.

But if we are impelled to the conclusion that the German means were inadequate for the attainment of their ends, we cannot but admire the skill with which they employed the means they did possess, and the real results which were secured for them in spite of their defeat. The stubbornness of the German defense on the first day of the Battle of the Frontiers and later at the Ourcq is beyond all praise. The skill of a staff which could maintain any kind of communications during the march of von Kluck's Army is marvelous. Those who read Sir Douglas Haig's last despatch will find that he had great difficulty in reversing the process during his march into Germany after the Armistice. In spite of the defeat at the Marne the first campaign put the war definitely on hostile soil and placed the theatre of operations in an area from which it was not removed for four years. That it unified the whole world against Germany is true; but such a unification, as all history shows, is the regular result of every attempt to become master of the continent. One can never escape the consequences of one's political ends.

There are two other criticisms directed against the German plan which are purely military in their nature. One is complaint of their failure to seize the channel ports. But such a criticism presupposes that the Germans from the beginning foresaw a complete stabilization. That, however, is just what they did not want. What they were after was a Sedan. It is true that d'Amade's Army could easily have been driven out by a few divisions, but what would have been the situation of the German High Command if the Battle of the Marne had been lost for want of two Army Corps attacking Boulogne and Calais. The Germans knew well that their means were slender. What they had to

do was to husband them, so that all could be on the field of battle on the decisive day.

The other criticism relates to von Kluck's change of direction on September 2nd. It is true that he might have captured Paris had he continued the march. But that also would have prevented a Sedan. The centre could not have advanced if the right had been tangled up with a siege operation. Whether such a capture by itself might not have ended the war is another question, and belongs more to politics than to military history. If the Battle of the Marne had been won, Paris would almost surely have fallen anyway. The Battle of the Ourcq, which was the direct consequence of the flank march, did not turn out so badly after all. The German High Command manifestly never repented the operation for it was von Hausen's head, and not von Kluck's, which finally fell in the basket.

But probably the most masterly criticism of the German strategy in the west, a criticism which is also a prophecy and in some respects an epitaph, is found in a book by von der Goltz, written many years before this wonderful campaign:

"The boldest and best plan will lead to ultimate failure, if the available resources do not hold out until we have successfully gained the final objective, the attainment of which ensures peace. This is most clearly shown in the case of great commanders like Hannibal, Charles XII, and Napoleon, who all failed in this one point and came to grief over it. These great generals resemble smart speculators, whose means do not quite suffice to carry their speculations right through, and who, through some final piece of bad luck, often in itself trivial, see all their brilliant winnings suddenly swept away."

Simple Method of Finding Safe Loads for Beams.

The safe uniform load W for any steel beam spanning 1 foot at an extreme fiber stress of 16,000 pounds per square inch will be $W = 10{,}670$ S, in which S is the section modulus. For ease in memorizing use $W = 10{,}000$ S, and if desired to be exact, add 7 per cent.

To find the safe load for any span, divide the value W so found by the span in feet. Thus, the safe uniform load on a 20-foot span of an 18-inch 55-pound I-beam (section modulus 88.4) is $10{,}000 \times 88.4 \div 20 = 44{,}200$ pounds, adding 7 per cent to make the result exact, 47,294 pounds.

For a load concentrated at the center of the span, take one-half of this result.

A similar rule for safe uniform loads on rectangular wooden beams is: For a fiber stress of 1,600 pounds per square inch the load for a span of 1 foot is $W = 175\ bd^2$. b being width of beam, d being depth in inches.—Extract, *Engineering News-Record.*

ROADS IN SUPPLY AND ATTACK.

By

Col. W. G. Caples,

Engineers, U. S. A.

ROADS.

In open warfare all supplies must eventually reach the troops by road. The road system must be sufficient to carry all the supplies from railhead to troops and should supplement the rail system to relieve the latter of a portion of its load and to tide over temporary breakdowns. Road systems in advance of railheads are supplemented by light railways, but cannot be replaced by them because of the greater adaptability and capacity of roads, their more rapid rate of advance in an attack, their smaller liability to break down, and their greater ease of repair. In stabilized warfare, ammunition especially, and to a less extent other supplies, may reach the point of use directly by light railway, but even in this case the road system must be sufficient to care for all supplies in the event of a breakdown of other means of transport.

The rate of movement of an army is limited by the rate at which it can receive supplies and this in turn depends upon the sufficiency of the road system and the rate at which it can be advanced. The great weight of artillery ammunition especially required that the road system be good to sustain a rapid advance. A modern attack can proceed no farther when it loses its artillery support for, with the narrow fronts and deep formations now employed, a defending force can develop a small-arms fire equal or even superior to that of a numerically much greater attacking force. On the other hand, with an attack once successfully started there is little reason why it should be halted so long as the artillery can continue to support with its initial volume of fire. The continuation of the artillery support is absolutely dependent upon having a transport system that will insure a continuous supply of ammunition. The rôles of the main arms of the service in an offensive have become:

Infantry; to assault with rifle and bayonet;
Artillery and machine guns; to support the assault by smothering the enemy with fire;
Engineers; to open and maintain the ways of communication upon which the support of the assault depends.

According to the officer in charge of motor transportation of the Mexican Punitive Expedition, an army may be supplied by road alone over a line about 75 miles long. Considering the relative rates of advance of roads, light railways and standard gauge railways, an assault once begun may continue to a depth of 200 miles before it has to halt and wait for the development of its ways of communication, assuming that no usable railways are found in the captured territory. In other words, an assault successfully begun may proceed to a decisive victory in a few days, provided that the communications can be advanced as rapidly as the infantry.

Losses in attack are very small so long as the attacker is advancing under the support of his artillery, because the defender is forced to concentrate his fire upon the leading elements of the attack, the location of which he is more or less uncertain. Once the attack is halted—and it will be halted the instant it loses effective artillery support—the defender will search with fire the whole area of the deep attack formation and punish the attacker heavily. If the attack be halted before it can reach the defense's artillery position it will probably be an expensive failure. Either the attacker must hold the ground and prepare a new attack at terrible cost, or he must withdraw under heavy loss and forfeit all his gains.

Adequate provision for the rapid advance of ways of communication will greatly cheapen the price and increase the measure of victory.

The ordinary ways of communication are roads, light railways and standard or broad gauge railways, each of which has its place, and, except for roads to a limited distance, can not entirely replace the others. Waterways and other modes of conveyance which are not of universal occurrence may be of very great value when encountered and should be used to the fullest extent, but the three ways cited are those which must always be considered in modern war. The adequacy of a road system to serve an army depends upon the quality and number of the roads themselves and upon traffic regulation. The huge amounts of supplies and the speed with which these must be delivered to a modern army demand the use of motor transportation, which in turn demands roads of the first quality. Mud or loose sand will effectually prevent the use of motor transportation. The weight of the vehicles and force of impact of the blows delivered by them in passing over irregularities at the high speeds employed are a severe test of both foundations and surfaces of roads. The destructive effect on a road surface of rubber tires and more particularly of chains is very severe.

The success of the French water-bound macadam roads in carrying motor traffic has led some to the conclusion that this type is universally most suitable for all military roads. The facts are somewhat different. France is generally a very wet country, where the normal weather for the greater part of the year is rain. Stone suitable for roadwork is widely distributed, generally near the surface and easily quarried, and is at once the cheapest and most available material. Repairs to macadam roads are made by putting fresh stone on the surface. In the wet climate of France the new material binds quickly and readily. Sprinkling is required only during a brief season in the summer and fall. By this process of repair the old roads have become very thick. The national roads, constructed initially 50 cm. to 60 cm. in thickness, are now frequently over 1 meter thick. Departmental (county) roads, constructed initially 40 cm. in thickness, are often as thick as the national roads. From 2 to 4 feet of metal, as found on these roads, so distributes the pressure that foundation failures are all but unknown except in the case of a sudden thaw following a heavy freeze. The latter condition is rare with the winter temperature of France and when it occurs traffic is kept off the roads. The French roads that correspond to the ordinary American macadam road are the community roads, which have a variable thickness of metal, but will run generally about 30 cm. No reliance is placed in these roads in planning operations unless their condition be exactly known. Under heavy motor traffic these roads fail quite as rapidly and effectually as any others of similar construction.

Even the very thick national and departmental roads are far from proof against the effects of truck traffic. The surface is soon picked into chuck-holes, which deepened rapidly under traffic and eventually destroy the trucks that cause them. Only by heavy and constant repair have these roads been maintained under military traffic. The number of men and the amount of transportation required for the maintenance of water-bound macadam roads in war are a serious drain upon the military resources of any country. The success of the system in France has been due to the fact that the roads suited the climatic conditions and were of the type most readily constructed and maintained with the class of material most available.

Permanent road construction is a slow and expensive procedure. Either a nation must construct its roads in time of peace or have its military operations hampered by the necessity of waiting for road construction during campaigns. The United States as a whole has its road system to build. There are large areas in which suitable stone is

scarce and the construction and maintenance of a macadam road from 2 to 3 feet thick would be more expensive than the use of better type roads of less thickness. There are still larger areas where the dryness of the climate during the greater part of the year makes water-bound macadam exceedingly hard to maintain and may even convert such a road into a heap of loose stones. In the vicinity of El Paso, it was found that the maintenance cost on the macadam portions of the military road system exceeded in six months' time the construction cost of concrete roads of equal length, while the concrete portion, which carried the heaviest part of the traffic, cost practically nothing for maintenance. Bitulithic stretches fared better than water-bound but failed under truck traffic. The conclusion is obvious.

In stabilized warfare, except for a zone 4 to 6 kilometers wide each side of the "front lines," roads suffer very little destruction from shell fire. Even 2 to 3 kilometers from the front line the damage is not very great. In open warfare the damage to roads from shell fire is remarkably small. The bombardment and slow barrages, accompanying the American attack of November 1, 1918, in the Argonne-Meuse, were probably the most intense in the whole war. An examination of this terrain and that of the 1916 battles around Verdun shows that the damage in two days of the American attack was generally greater and the ground more thoroughly covered with shell holes than was the case around Verdun in nearly a year of continuous battle. Yet, even under this superlative bombardment, the roads suffered very little damage and none that could prevent their being made passable as rapidly as infantry could advance.

A road occupies very little space and, even if made the direct target, is very hard to hit, and, further, the metal surface is an excellent "shell-burster" course. With the ordinary variation in ammunition, if the first shot secured a direct hit on a road, the next direct hit might easily require the expenditure of $1,000.00 worth of ammunition and, after all, the net damage is relatively slight. The destruction of roads by artillery fire is not a paying proposition and is little undertaken. The repair of all the shell holes in 2 kilometers of road, exposed to four years of raking fire and on a battle-field where the French alone had lost as many men as both sides combined at Gettysburg, required only part of one night's work by one engineer company. Cross-roads, being sensitive points, are peculiarly subject to artillery fire, but roads in general will suffer only from chance hits.

Concrete roads could not be used during the late war because the

scarcity of coal in France limited the burning of cement to such as was absolutely necessary. The repair of a shell hole in a concrete road should be no more difficult than in a macadam one. The hole would be filled with stone and traffic carried over it until such time as a concrete patch could be placed. Maintenance on concrete roads would certainly be far lighter than on macadam ones and maintenance in war means not merely money but, what is more important, men and transportation drawn from a nation's war resources. There is nothing in recent war to show that concrete roads, with or without other wearing surface, are other than the best motor roads in war as they are in peace.

Whatever type of road be constructed for war purposes, it must meet the conditions of being able to carry the heavy and long sustained motor traffic; it must be suited to the climate and readily repaired with easily available material.

The capacity of a road is regulated by its quality and type and by traffic control measures. A poor road may have no capacity at all, while the best road will equally have none under poor traffic regulation. On good roads horse transport may be counted upon to move 2.5 miles per hour with one vehicle per 20 yards and average one net ton per vehicle; giving for a continuous column of horse transport about 200 tons per hour. Motor transport, under similar conditions, will move 12.5 miles per hour with one vehicle per 75 yards and average two net tons per vehicle—giving for a continuous column about 600 tons per hour. Crossings, breakdowns, and other causes of delay prevent the use of continuous columns and reduce the capacity of a road at least one-fourth. For a good 3-track 2-way road, operated all day and all night, 3,000 tons each way by horse transport or 10,000 tons by motor transport may be taken as a working maximum capacity.

Within the limits of enemy observation and shell fire or where an active enemy has air superiority, movement is possible usually only at night and without lights. The speed of motor traffic must be materially reduced. Under such conditions 1,000 tons by animal transport or 3,000 tons by motor transport may be taken as a working maximum.

It should be noted that these conditions do not apply to the first day of an attack, nor to later days, so long as the attack is going forward and the airplane barrage remains essentially perfect. Under such conditions troop concentrations and road movements that in full daylight would ordinarily be suicidal may be undertaken almost with impunity.

A 2-track 2-way road has the same capacity as a 3-track 2-way road, but is limited to one class of transportation at a time. Motor

transport can not work economically at the speed of horse transport and will invariably try to pass the latter. On a 2-track 2-way road such procedure will result in road blocks that will stop traffic entirely. The best form of roads is a 1-way loop, that is, traffic exclusively "up" on one road and exclusively "down" on another. On such a loop-road the traffic is to a certain extent self-regulating and the condition of a continuous stream of vehicles may be more nearly approached. If the loop-road have two or more tracks one may be assigned to animal traffic and one to motor traffic and the two types of transport may thus be used simultaneously on the same road. The use of the loop form of road results practically in a notable increase of capacity due to the marked reduction in blocks. For this reason roads are assigned as far as possible in the form of loops, even at the expense of requiring two troop divisions to use the same loop.

Roads leading to the front are known as axial roads; those generally parallel to the front as belt roads. The greatest traffic congestion is in advance of the line of advance railheads (that is, railway unloading points), for beyond this line transportation is largely by road. Back of the line of advanced railheads is the main supply area, in which are other railheads and the main depots of the corps and army. Transportation from this area is by road and by light (60 cm.) railway to the front. The 60 cm. lines have a practical capacity of about 750 tons of heavy artillery ammunition or 500 tons of supplies per line per day. In general the number of lines that can be provided will suffice to carry only ammunition and engineer materials, while frequently only ammunition can be supplied. In advancing 60 cm. lines, 35 trains are required to transport 1 mile of track and the capacity of a line will generally not exceed 48 trains daily, which limits the rate of advance of these lines to about 2,400 yards per day. Unless captured 60 cm. lines can be used an advancing army quickly becomes dependent upon roads alone. Practically always a portion of this transportation from supply area to troops must be by road. Back of the army supply area is the general network of roads of the country and the road requirements of an army are normally much less than the capacity of this net. The zone in which the road system must be specially arranged for an army is from the rear line of the supply area to the front line of the army.

The critical case in road assignment is for an advance. Assignments for other operations are along the same general lines, though much simpler because of the aid given by other ways of communication and

usually also by reason of the better condition of the roads. Certain general rules should be followed in road assignment:

(*a*) The roads assigned each unit must be sufficient to carry all its supplies and lie, as far as practicable, within the sector of the unit;

(*b*) The responsibility for road control and the responsibility for road work should be coterminous, and vested in the same staff officer;

(*c*) Where two or more units must use the same road or one unit must use a road in the sector of another, control should remain vested in

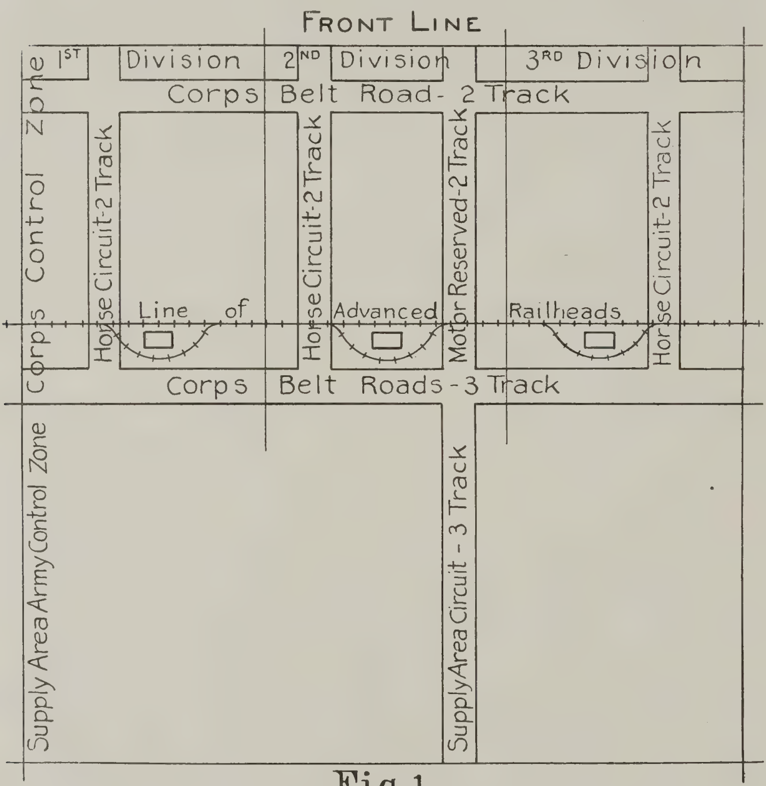


Fig. 1.

Minimum Road Requirements of a Corps.

a headquarters having command of all units concerned. Road work in this case may be an exception to rule (*b*) if the road lie in advance of the normal zone of work on the headquarters, and the road may be divided into sectors, one sector being assigned to each interested unit for road work.

The distribution problem concerns generally the axial roads, as *traffic is largely axial*. Belt roads should, however, be designated for

the full width of the area to insure the belt road work and circulation in the various sectors.

Army headquarters generally will retain control of all roads in rear of the line of advanced railheads because all units are interested in the supply area. Each corps must be guaranteed an axial circuit in the supply area upon which it can locate its reserve supplies. *This circuit* may be either a 3-track 2-way spur or a 2-track loop and *is a minimum*

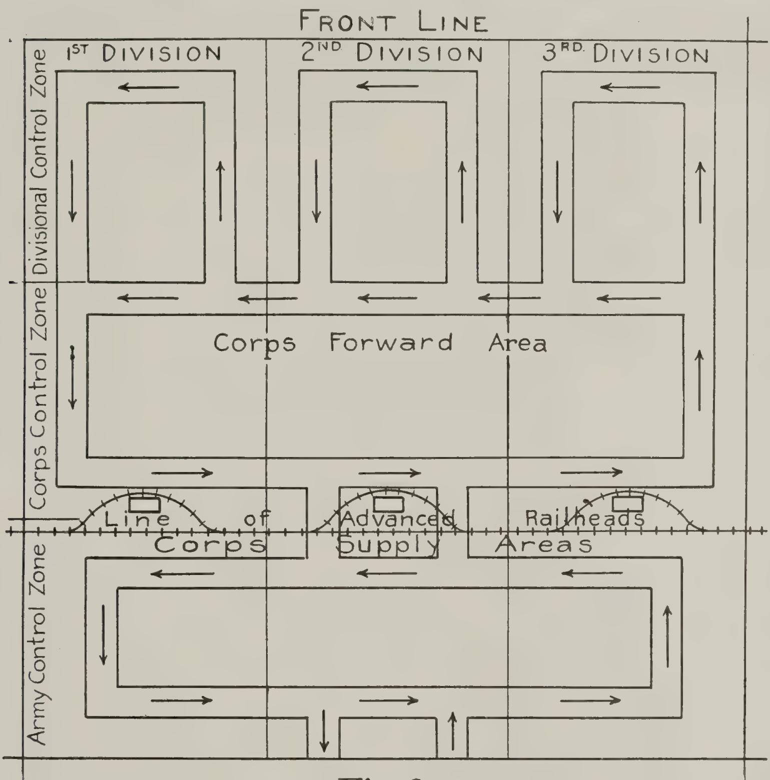


Fig. 2.

Ideal Road System for a Corps. All roads 2-track 1-way. Arrows show traffic directions.

road requirement. Unless the roads forward of the line of advance railheads furnish the following *minimum accommodations* for each corps, army headquarters should retain control of sufficient roads in adjacent corps sectors to guarantee these road accommodations to each corps:

One motor circuit, either a 2-track spur or a loop;
For each division, a horse circuit from its railhead;
The same circuit may serve two divisions.

The minimum road requirements are determined as follows: A corps of three divisions actively engaged will require a daily supply, principally by motor, of artillery and engineer supplies approximating the full capacity of a 2-track road. These supplies will come partially from railheads, but principally from reserves in the supply area. A limited amount will be carried from the supply area by horse transport. Rations and other automatic supplies will be delivered principally at railheads and moved to divisions by both horse and motor transport.

Ideal road conditions are obtained when all roads are in the form of loops, although the amount of horse traffic in the supply area is so small that a 3-track 2-way spur may be considered ideal for the corps back area.

The obtainable road conditions will generally be somewhere between minimum requirements and ideal conditions.

The distribution of roads by each corps to its divisions is made along the same general lines, roads in which only one division is interested being assigned thereto and the remainder being retained by corps. Metaled belt roads are generally retained by corps. As far as possible each division is given one metaled axial road commencing at its railhead but under corps control to the limit of the corps zone. Frequently two and sometimes even three divisions must be assigned to the same axial road. With a system of metaled roads, such as is found in France, unmetaled roads are generally not mentioned in the assignment and are at the disposal of each division in its zone and sector. The natural boundaries of zones are the lines along which common interest ends and individual interest begins. Except in an advance, army common interest will end about along the line of advance railheads and corps common interest will end near the line of division P. C.'s, which makes these lines suitable for dividing the zones of army, corps, and division control.

In an advance the case is somewhat different. Divisional engineers are supposed to make the roads passable and no more; but, as "passable" for the modern division means ability to take the sustained traffic of 3-ton trucks, including bridge structures able to bear a 7.5-ton tank, making a road "passable" amounts to a first-class and thorough repair job. Corps troops, being no better equipped than divisional troops, can do no more. The corps park may provide pile drivers and pontoons for special work, but, in general, the class of work done by corps engineers differs not at all from that done by divisional sappers. Reconstruction and new construction of the character of a metaled road are the functions of army troops, who are alone equipped therefor. This class of work cannot proceed as rapidly as a successful advance.

Divisional troops should be kept with their divisions, leaving an ever-widening gap between the rear of the divisions and the head of army construction as the advance proceeds. Corps troops should maintain the roads in this gap. The natural division of duties on roads in advance becomes:

Divisions: Repair;
Corps: Maintenance and special work;
Army: New construction, reconstruction, and maintenance.

The idea that divisional engineers do one class of construction later improved by corps engineers and erect structures later strengthened by corps engineers finds no place in the field and should find none in texts. The roads must carry immediately all the division's supplies and the division will advance no more rapidly than its roads, for to do so is to lose its artillery support.

In preparing for an attack the roads will be found good and sufficient usually to within 2 miles of the enemy. This condition is almost necessarily true after a period of stabilization, as during such period roads will have been built to meet all needs of the sector. The same conditions probably will exist on the side of the enemy. Therefore at the beginning of an attack there is no natural zone between divisions and army for the corps troops. On the other hand the most critical situation as regards ways of communication is the crossing of this 4 or 5-mile gap between the good roads of the attacker and those of the defender. Here the roads will be found in their worst condition, and more effort will be generally required to establish communication than at any other stage of the offensive. Yet this communication must be established and pushed forward as rapidly as the infantry advances unless the offensive is to suffer a very expensive check. More often than not, this task in the early stages will require more men than the divisional engineers have, while later on a single engineer battalion will frequently suffice. The corps troops must share in the work of crossing "No Man's Land."

The system of allotting the roads in "No Man's Land" up to a certain line—generally the parallel of departure—to corps and beyond to divisions is *not* to be recommended. The work must start where the roads become bad and proceed without interruption. The divisional engineers require the use of the roads to bring forward their road material and *each division is vitally interested in its roads in their entirety from the very start, not merely from some advanced line crossed during the attack*. The repair of its own roads belongs distinctly to each di-

vision and higher headquarters should keep hands off this work. The corps troops required to supplement the divisional troops, and for special bridge work, should be temporarily attached to the divisions and the divisions alone should be responsible for opening the roads. As rapidly as the need for corps troops with divisions passes, these troops should be withdrawn and assigned to maintenance in the gap formed in the course of the attack between divisions and army.

The experience of the 1st Division of the American Expeditionary Forces in the St. Mihiel offensive is a practical example of the working of the opposite system. Some corps troops were assigned divisions, but the corps announced that it would take over the roads south of a certain line, well inside the German position, on D day and H hour. With this assurance the division planned the use of its engineers. Fortunately the demands of the artillery and medical chiefs for special road work in the corps zone and in excess of the one road guaranteed by corps caused some engineer troops to be held by the division in the corps zone, but the bulk of the engineer troops were assigned to lead the assault and facilitate the passage of infantry and tanks. When the corps troops failed to arrive at the appointed time, a small force was raked together and put on their work. This force, although insufficient, carried things through the day of attack. That night, the engineer troops with the tanks were released and put on the roads. At the same time the engineer troops with infantry were ordered released, but the order failed of delivery at the proper time and these troops were not collected until the next afternoon. Changes after an attack is launched are well known to be all but impossible. Requests and a personal visit to the corps consequently brought no result. By the next morning, not only corps but army were aroused and sent representatives who commenced to order up troops. About noon of the second day the corps troops commenced to arrive, over 30 hours late. By four of the same afternoon the divisional troops who had been working or fighting for forty-eight hours continuously without rest were utterly exhausted and were relieved from work in the corps zone. It appeared from questioning the officer with the corps troops that instead of opening all roads simultaneously, work had been taken up in the several roads in turn with the result that the division last in order had to do the bulk of the corps work in its sector and had to do it with means improvised during battle. On the third day, after the trouble had been fairly well ended on the second, the work was abundantly supplied with troops whose presence on the first day would have avoided all serious difficulty in so far as construction was concerned. It must be borne in mind that combat

involves the meeting of urgent emergencies in road matters as in all others, and that the highest headquarters which can meet these emergencies on the spot is the division. Considerations of time and space make it impossible to expect rapid changes by corps and still less so by army.

The road work of an attack commences simultaneously with the artillery preparation and may go to the extreme front line before the infantry moves. During this period the hostile infantry and machine gunners are usually forced underground and the defender's artillery is silent or forced to turn its attention to the batteries of the attack. Scattered groups of men and some trucks and wagons at wide intervals along a road offer small attraction for a battery which is itself under counter-battery and they may even escape detection altogether on a dark night. Hostile batteries overlooked by the attack may, and probably will, shell the roads but some work will generally be possible and the time gained thereby is worth no small risk.

Road plans for an attack include the opening of supply lines and the movement of divisional artillery; the corps and army artillery in general follow supply lines in their movement. Army headquarters plans for the roads that it expects eventually to control and maintain (often for a considerable distance beyond the front), and designates the main supply system. As a minimum the army staff must provide a traffic circuit for each corps to the existing supply area and to any new supply areas that it is intended to establish.

Corps plans as to roads should be more in detail and made in coöperation with division staffs as far as practicable. The opening of the army roads, the establishment of corps belts, and the preparation of axial circuits, preferably one for each division, require consideration. The trails required for divisional artillery movement should be considered in order to determine the total number of troops required for roads by each division. On a front of 2 miles or less one axial road and one trail will generally be ample for artillery movement. Division plans are made along the same lines as corps plans. A special subject for divisions is the utilization of trails for horse traffic and troop movements, especially in dry weather.

The tendency to provide too many roads, and thus fail to get any because of the insufficiency of the construction forces available, must be guarded against. The estimate of men required is an important one and should be liberal for the work finally ordered, since, unless the roads, and with them the ammunition supply, can keep pace with the infantry, the attack is normally limited strictly to the initial artillery range, 3 to 4 miles at most, and must then suffer an expensive check

if it meets with any resistance. The barrage table thus becomes the guide. Because of the frequency with which the more rapid barrages outpaced the infantry and the disaster attending such occurrences the tendency in the last days of the late war was toward very slow-moving barrages. The marked success at small cost attending the use of barrages averaging, including halts, 100 yards in 8 or even more minutes argues for the continuation of these barrage rates. An uninterrupted attack therefore calls for a general advance of artillery within 8 hours at most. A good plan in estimating is to divide the work into tasks readily accomplished by one company in 8 hours. The troop distribution should be such that the artillery movement to an intermediate position about 2 miles in advance of the first can commence within 4 hours after the infantry advances.

A good labor distribution is the following: Estimate the work in each division sector and allot corps troops to each division to make up any deficiency in the number of troops required in its sector. From any corps troops remaining, allot one company for maintenance in each division sector and hold a reserve of one battalion to meet any contingencies that may arise. If any corps troops still remain, allot them to those divisions having the most difficult work. The engineer troops, trench mortar battery and, if need be, other troops from reserve divisions may form part of the corps troops for road work where the numbers available are otherwise insufficient.

Road estimates in the attacker's lines are readily made by direct reconnaissance, but those in the defender's lines are based upon maps, air photographs, and information of the country especially as to streams and their characteristics. The last is often remarkably contradictory. The worst conditions reported should be guarded against. Maps give the general road system, the stream crossings, and those points where the enemy may advantageously blow up the road or otherwise cause serious delays. Air photographs give existing conditions and are invaluable. Dimensions can be scaled from them and the work estimated quite closely. Other information is useful principally in connection with the type of structures required and particularly as to whether trestles will serve or piles must be used for bridges.

Materials should be assembled into convenient dumps to meet existing conditions with such allowance as practicable for probable demolitions. Arrangements are made to promptly search out and utilize captured dumps but the attacker's dumps should be sufficient in themselves. Bridges should be rough framed, the pieces marked, and made into standard loads. An excellent form of wide application is a trestle bridge of 8″ x 8″, 3″ x 12″, and 2″ x 4″ timber only. This bridge will

carry army loads, requires in erection only such adjustments as can be made with blocking or a saw, and is quickly erected. Tools required should be placed in the dump. Trench bridges should be made up in portable sections ready to be laid side by side, spiked together, and provided with a good wheel guard (6″ x 6″ or 8″ x 8″). The wheel guard is quite important, as a truck skidded with its hind wheels on the bridge and its front ones firmly wedged in the trench requires much time to dispose of with the means ordinarily at hand and meantime constitutes a most effective road block. Special appliances (pontons, pile-drivers, etc.) should be conveniently assembled.

Where the prospects are that a considerable structure must be erected under fire, arrangements should be made for artillery support and especially for a wide, deep smoke barrage in connection therewith.

Methods are a matter of judgment in each case. The trestle bridge gives quickest results and is preferable wherever the foundation admits. Mine craters are crossed quickest by bridging, as a rule, because the locations selected for mines are where a shunt road or detour will be peculiarly slow and difficult to build. Shell holes require filling *solidly* with good material, stone, brick or tile preferably, or, failing these, woven brush. Earth alone makes a mud-hole exactly as deep as the shell hole and is too soft for trucks even in dry weather. Earth-fill and stone-cover results in a bad cup after rains. As shell holes require easily a truck load (1.25 cubic yards) of stone each and as there may be from 30 to 50 per mile in an average "No Man's Land," wheeled transportation is essential to speed. Collecting the material with sacks and barrows is a fruitful cause of serious delay. Portable bridges are the quickest and most reliable trench crossing. Scraping the sides will do for trials but gives too soft a bed for trucks. Blowing in the sides shatters the earth underneath and prepares for a quagmire with the first rain. Road-plank (8″ x 8″ stringers and guard; 3″ x 12″ flooring) are invaluable for crossing soft places. Obstacles require stout gloves, heavy wire-cutters (bolt-clippers or equivalent), axes, and spike poles. Fondling a fretful porcupine is nothing compared to handling, without the aid of a spike pole, a steel cheval-de-frise wrapped with military wire.

Time required varies with conditions. Rough average 8-hour tasks for a company are:

35 yards of trestle bridge;
600 yards of plank road or road badly cut by trenches;
1,200 yards of average "No Man's Land" road;
2,400 yards of average road beyond "No Man's Land" (2 miles from front) or artillery trail.

It is well for the corps staff to order the minimum force to be placed on the supply-road system in each division sector. Corps have not the same temptation as divisions to fritter away road troops upon other and generally less important duties, especially in the earlier

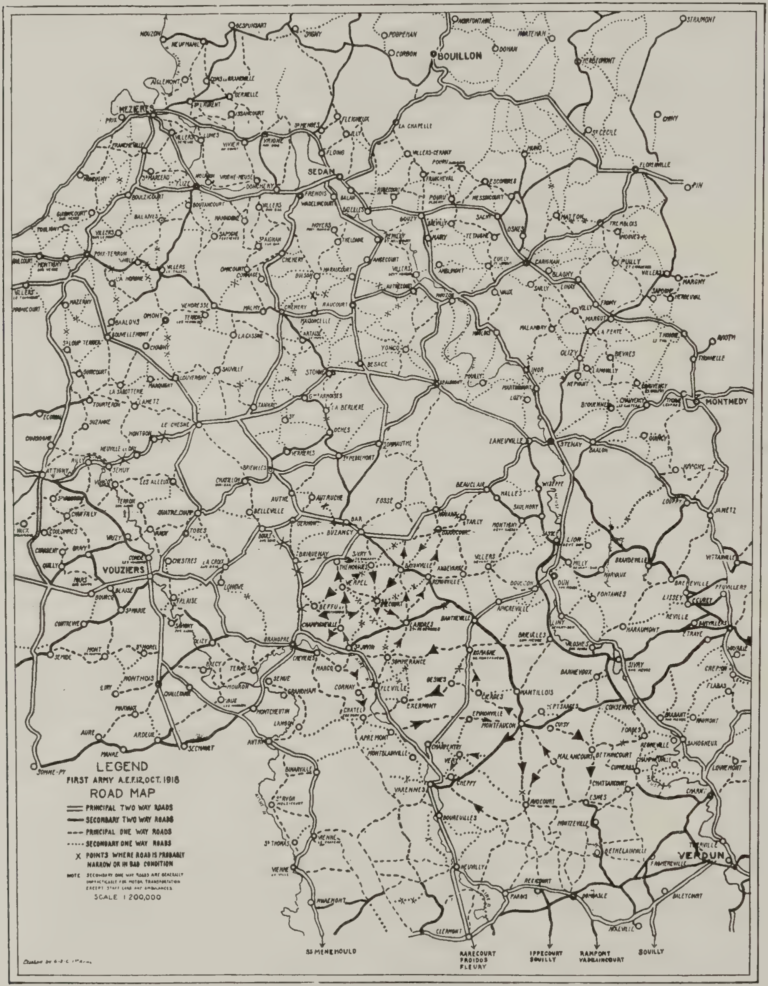


Fig. 3.

stages of a campaign before the value of roads has been learned by experience.

No matter what the quality of the roads nor how well planned the system, nothing will travel unless there be good traffic regulations. In unregulated traffic every one tries to pass every one else, road blocks result, and no one moves.

(See Fig. 3—1st Army road map—attached.)

Fig. 3 shows the traffic plan of the 1st Army for the Argonne-Meuse offensive. The situation was a peculiarly difficult one, as the roads were insufficient in themselves and practically all traffic had to pass through the two bottle-necks, one at Varennes and one at Avocourt. The solution planned was excellent but inadequate regulation caused serious blocks, the one at Avocourt being probably the worst experienced by the army and amounting to a suspension of traffic for more than a day.

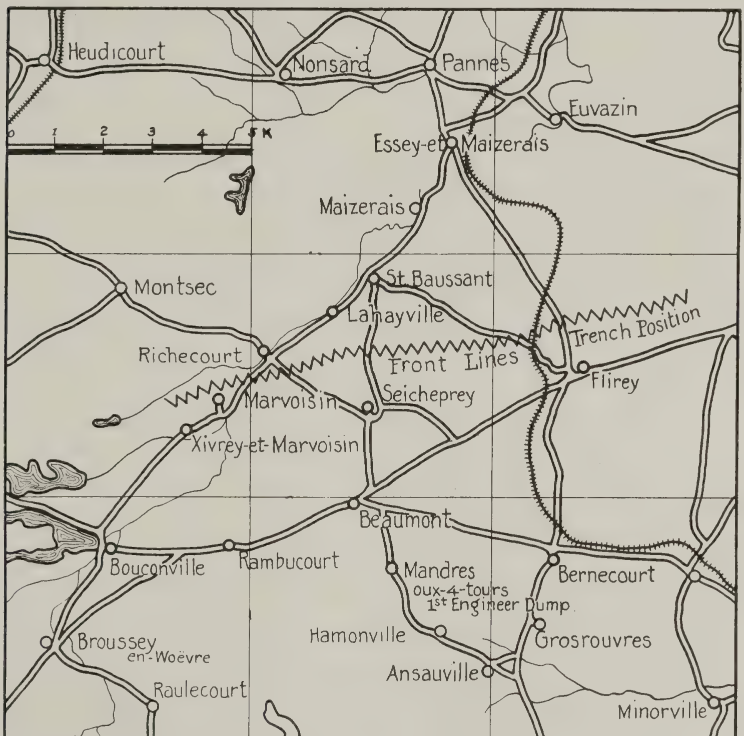


Fig. 4.

The lessons learned here and at St. Mihiel were so impressive that traffic regulation became almost a fetish before the campaign closed.

The road blocks of the 1st Division at St. Mihiel are a typical example of unregulated traffic. The 1st Division axial road was Beaumont-St. Baussant-Essey-Pannes. That of the division on its right was Flirey-Essey-Pannes, the two coinciding from Essey to Pannes. The 4th Corps assumed responsibility on D day and H hour south of a general east and west line through Lahayville but guaranteed only the road Beaumont-St. Baussant in the 1st Division sector.

The 1st Division engineer dump was located in the ruins of Mandres. The road Bouconville-Beaumont-Bernecourt and roads to the south, Buconville-Xivray, and roads north of St. Baussant were generally good 2-track highways with some shell holes as far as Essey. Xivray-St. Baussant was an old 2-track road full of dugouts, cut and narrowed by trenches to 1-track width. Beaumont-Seicheprey was an old 2-track roadway narrowed by trenches in places. Seicheprey-St. Baussant was an old 2-track way narrowed practically all the way to 1-track width. This road and the one preceding were much cut by trenches and mined by dugouts. The road Richecourt-Seicheprey to Beaumont-Fliery road crossed both trench systems and was practically obliterated. Troops intended for this trail were shifted into Beaumont-St. Baussant road when no corps troops arrived. A few days previous to the action, Rambucourt-Xivray was repaired and made a passable 1-track route. As soon as the action permitted, Xivray-St. Baussant was undertaken for work. Several artillery trails were opened. Bridges were built at Richecourt and Lahayville. A German bridge was found at St. Baussant with the demolition charges built solidly into the concrete. The fuses were pulled and the bridge used. The 1st Division artillery advanced by the trails and bridges noted. The sector was one that had been stabilized for four years. The roads for 2 miles each side of the front lines were much cut by trenches and had many shell holes.

Despite the inadequate force, the road was opened from Beaumont to a short distance beyond Seicheprey and work was in progress to St. Baussant by noon of the first day. At this juncture a 3-ton medical truck followed by a string of ambulances dashed madly down the road into the first piece of unfinished work and stuck. The block was started. Everything else—a one-horse sulky, wagons, carts, kitchens, trucks, tanks, the transportation and artillery of the division on the right, and one man with a baby buggy—poured into the road, filled it solid from ditch to ditch and the block was complete. Any hope of getting forward road material was gone. The inadequate working party had to use what it could pick up in the trenches. The seething mob in rear poured across each piece of work as soon as it could be crossed at all, generally destroyed work done and blocked itself again, until finally it had the road solidly full to St. Baussant. Anything that reached St. Baussant went on readily. The stretch from Beaumont to beyond Seicheprey, which had been repaired before the mob struck it, gave no further trouble, but the stretch beyond to St. Baussant, where the traffic was overrunning working parties and destroying half-finished work, was repeatedly (and practically continuously) blocked.

Shortly after the middle of the afternoon arrangements were made to concentrate efforts on the Xivray-St. Baussant stretch and slip the 1st Division ammunition around that way before the mob pouring in from Mandres and Bernecourt found out what was happening. A little later a French truck train reached Mandres from the southwest, planted itself squarely across the stream of traffic and filled the streets solidly. Some military police had been doing good work here, but the French drivers exhibited wonderful proficiency in their inability to understand either English or French as spoken by an American. A staff car, cut off by this train as it first arrived, required an hour and a half to return to Beaumont. All hope of getting anything more from the dump was gone. The party on the Xivray-St. Baussant road was reduced to working with what it could pick up and the material assembled in Mandres remained there.

The two streams of traffic meeting in St. Baussant caused a handsome block at that point. Near 1:00 a. m. of the second day the division commander ordered the road opened beyond Seicheprey. At this juncture an engineer company that had been working steadily with the tanks for the past 30 hours was released and came into St. Baussant to rest. A captured engineer dump was located here. A truck skidded off a bridge into a trench and blocked the road near Seicheprey. This truck was allowed to remain as a block for the time being. The road was cleared ahead by forwarding traffic through St. Baussant. Then with captured material and working from the direction of the enemy, the troops who had fought with the tanks opened the road. A tank was gotten to knock the stalled truck off the road and hold back traffic until the damaged trench bridge could be fixed. Traffic proceeded at 5:00 a. m. of the second day.

Within an hour traffic was stalled again. Return traffic tried to come down the road and made a new block at St. Baussant. The old jaded animals, none too good to start with and not improved by heavy service, could not pull their loads up the grades and so stalled. Impatient motor drivers tried to pass on a 1-track road, stalled, and made new blocks all through the line. The division commander then ordered the division engineer to take charge of the military police and regulate the traffic as well as prosecute the road construction.

The first step was to clear the roads absolutely by turning everything except road parties into the fields. A traffic loop was then established. Up-traffic used the line Beaumont-St. Baussant and down-traffic the road St. Baussant-Xivray. Beyond St. Baussant the traffic was both ways. The vehicles were forced to remain in single columns.

"Snatch teams," taken from the engineer transport, helped on the grades until noon, when they became tired out. By this time the bulk of the traffic had passed. A traffic control post was maintained at St. Baussant. About noon the corps troops began to arrive and relieve the exhausted divisional troops who had been working, or working and fighting, for two days and nights and were at the point of total exhaustion. Traffic blocks, except those due to exhausted animals, were practically over by noon and the relief by corps troops was completed about 4:00 p. m. of the second day.

The account of the road troubles in the St. Mihiel action may make it appear that no road blocks should have occurred. That is true and no blocks will occur if adequate provision be made for road repair and traffic regulation, but if either point be slighted there will be no road traffic.

Traffic control depends primarily upon march discipline and a reasonable regard for the rights of others. Despite the fact that common politeness is the basis of march discipline, the worst offenders are frequently officers of comparatively high rank. Primarily it is the line officer who must teach and enforce march discipline. Five simple rules cover the duties of a column with respect to parallel traffic:

> Keep to one track;
> Keep to the right of the road;
> Don't double-bank;
> Don't halt on the road;
> Clear your track of obstacles.

The first two may be combined for roads of more than one track by saying: "Keep the left of the road clear." Double-banking is trying to pass a column moving in the same direction, and causes blocks by meeting traffic from the opposite direction. When one column overtakes a slower one, the temptation is strong to commit this deadly sin against good order on roads. With each column on one track, a halt anywhere on the road halts the whole column. The road must be cleared at once to let the remainder of the column proceed while a portion is halted. Unless obstacles are cleared, the column must leave its track, usually with the effect of taking the other track and blocking traffic from the opposite direction.

At halts and crossings these rules apply:

> A moving column has the right of way over any portion reentering from a halt.
> Main road traffic has the right of way over that from side roads.
> Axial traffic has the right of way over belt traffic.

Free circulation must be guaranteed staff cars and messengers, who must visit all parts of the column, but even they are subject to the rule that—

A column has the right of way on its own track.

The long, closed-up columns formerly used in our army are not only excessively fatiguing to the troops, but are a complete road block and impossible to negotiate readily by messengers. The French system (a modification is used by the British) generally adopted by the Americans overcomes these difficulties and is to maintain 500 to 600 yards distance between battalions of infantry and units of equivalent length (450 yards). The spaces take up column elongation and eliminate the excessive fatigue of marching in long columns, provide places for staff cars and messengers when the left track is in use by traffic from the opposite direction, and permit the crossing of two columns without interruption to the march of either by permitting each to march across the gaps in the other. The passage of messengers and staff cars along a transport column is guaranteed by maintaining a gap of 25 yards behind each six vehicles—whether animal-drawn or motor—and 50 yards between convoys.

March discipline is a part of training which can not be left for the campaign without excessive cost. Every movement of troops or transport in garrison—even the simplest movement in connection with routine duties, and at maneuvers—should be carried out in strict accordance with the rules of march discipline to make this discipline a fixed habit. Maneuvers are required for instruction in the march discipline of large units which is *not* taught by camping a division at the railhead and allowing its transport to cover the front of an army.

The staff officer's share in traffic regulation consists in foresight in providing an adequate road system, the preparation of reasonable traffic regulations, and strict enforcement of regulations made. An inadequate road system, poor traffic direction, needless or irksome restrictions, and lax discipline are fruitful of traffic congestion.

Unless the road system will provide the minimum accommodations above noted, the front should be widened or new roads built to give these accommodations before an advance is begun. The enemy is under the same necessity. The case where the roads must fit the plans rather than the plans must fit the roads is exceptional. Traffic directions should be carefully planned to give a continuous and natural flow of supplies to the front and of salvage to the rear. Forced and unnecessarily artificial conditions are soon recognized by all who suffer there-

from and cause a general disregard of regulations. The American soldier reasons quickly and submits readily to any reasonable regulation, but carelessly planned regulations that unnecessarily restrict him destroy his confidence and are promptly resented; whereupon he sets out "on his own" with a general disregard of all orders.

The separation of motor from other traffic is an important matter. All advantages of the speed of motors is lost—not to mention the extravagant fuel consumption caused—if they be required to wait behind the troops or horse transport columns that they overtake. Such waiting is particularly irksome on the motor drivers and leads to double-banking. Under proper methods the principal motor circuits are prescribed and maintained by army for the heavy traffic and are generally free to all motor traffic, but open to no other except by special permit from the army headquarters. These circuits are called "reserved roads." In special cases the reserved roads may be made "guarded routes," upon which motor convoys are dispatched at regular intervals and operated in the same manner as railway trains. This condition arises when railway transportation is inadequate and supplies must be transported by motor for long distances. When corps receives its road allotment from army it endeavors to extend the army system by corps reserved spurs and loops so that the whole corps area may be served under a reserved system. Divisions are fortunate when they have the exclusive use of one good road but can aid materially, especially in dry weather, by the development of trails for animal transport.

Road congestion will be relieved greatly by bearing in mind the principles of railway operation and providing for terminals and sidings even at the expense of some new construction by divisions. Distributing points, water refilling points, dumps, hospitals, transport parks, and similar places which correspond to terminals or where congestion is likely, should be on spurs or loops *off the main road.*

The operation of a road system requires an adequate supply of signs. Each village or cross-road should be provided with signs, conspicuously placed and showing the direction and the distance to all points in the vicinity. Villages should have these signs at all entrances, and in addition the name of the village should be conspicuously posted at each entrance. The Germans, in some instances, painted road maps on blank walls at village entrances. Roads under traffic restriction, enemy observation, or shell fire should be plainly marked with the appropriate information. In a stabilized sector a complete system of standard

signs on tin is soon arranged. In an advance the problem is more difficult.

The British system deserves special mention. The main signs are plain blackboards prepared in advance. As the attack proceeds each board is posted and marked with chalk. Lettering with white paint follows when and if necessary. Each motor vehicle carries a blackboard about 22″ x 30″ and a yellow arrow about 6″ x 20″ with the word "Lorries" painted on it in black on both sides in such a way that the arrow can be put up to point in any direction. Each horse-drawn wagon carries a similar white arrow marked "Horse T." These signs are improvised by the units, handed over to an assistant provost marshal on demand, and replaced by the units. Marks to be immediately placed are:

Direction-arrows on traffic routes;
Cautionary signs at dangerous corners and grade crossings;
Signs restricting routes to certain classes of traffic;
Road-direction signs.

The road system selected and marked requires to be policed by a system of control posts at all road crossings and junctions to assist and regulate traffic, and mounted patrols on the roads themselves to enforce traffic rules. A single unguarded crossing or junction in advance of railheads is a first-class guarantee of a road block that will extend for miles. Patrols are an indispensable safeguard against double-banking and other causes of blocks between control posts. Men on patrol and at control posts should be armed and authorized, if need be, to use their arms to enforce traffic regulations.

Although the military police are to enforce traffic regulations, the primary purpose of both the police and the regulations is to facilitate traffic. In this, the polite but ignorant military policeman who answers all questions with the patent falsehood: "Sorry, sir. I just got here today," fails utterly. Each traffic control post should be furnished with a hand board on which information as follows should be pasted and varnished to resist the weather:

A road map of the vicinity showing traffic routes, restricted roads and traffic directions with names of all prominent localities. In the case of posts in towns, a map of the town should be added.
A copy of traffic regulations.
Instructions as to action in case of blocks.

A sentinel at a control post should be able to give the following information instantly:

Points of the compass;

Location of towns and prominent points and roads leading to them;
Principal traffic regulations and reasons for all traffic regulations;
Information as to roads, number of tracks, one or two way, condition, restrictions, dangerous points, and where congestion may occur;
Alternative routes between principal points, including instructions how to enroute traffic in case of block within radius of 10 kilometers.

The traffic signals for "Slow down," "Stop," "Come ahead," "Go in that direction," should be published in orders and known by every driver as well as all military police.

The duties of a control post are to:

Require all traffic to follow prescribed routes;
Regulate passage to prevent blocks, and to keep all vehicles moving at points of probable congestion;
Stop, turn back, and report all traffic moving contrary to prescribed directions unless provided with written permit from corps or army;
Stop speeding and report offenders;
Reroute traffic stopped by blocks;
Assist traffic by information.

Traffic regulations should be published in orders and cover the following points:

Speed Limits. These should be suited to the roads and the traffic. As a principle, as much advantage should be taken of the speed of motor transport as the condition of the roads and the density of traffic will permit with safety. The following are good for average conditions:

Class of Traffic.	*Speed in km. per hour.*
Messengers and staff cars with officers	No limit.
Motor-cycles	40
Motor-cars	35
Trucks, 1-ton and under	25
Trucks, over 1-ton	20
Tractors	12

General Rules. Officer in charge of convoy is responsible for knowledge of traffic rules. All drivers must know, before march starts, either the destination or where to meet guides. No double-banking. Single disk on *both ends* of each sixth vehicle to be plainly visible and not approached closer than 25 yards by another vehicle. Double disk on *both ends* of last vehicle in a convoy unit to be plainly visible and not approached closer than 50 yards. Clear roads immediately of

broken-down vehicles. No halt on road. Keep left of road clear. Approach grade crossings slowly, halt 25 feet therefrom and signal for gates to open. If halted by control post, stop 50 yards therefrom. In absence of military police senior present is responsible for clearing road block. Report road block to nearest control post immediately. Mounted troops have right to inside of road on canal bank. Main-road traffic has right of way.

Motor Transport Rules. Move independently of other transport. Loaded convoys have right of way. Each car to have lookout at rear, *at all times when on road,* with readily workable signal to driver. No parking on road. If road can not be completely cleared at halt, move as far to side as possible and maintain distances and lookouts. Traffic posts will not order motor traffic into roads unsuited for motor transport. Ambulances follow motor circuits unless otherwise authorized in writing by corps or army and then only when road is empty of supply vehicles.

Animal Transport Rules. No trotting. No exercising of animals on traffic routes. Not more than prescribed load and personnel to be carried. Keep to prescribed routes. All ranks, mounted or dismounted, march in column, *not* to side. Animals to be tied to vehicles only in emergency.

Miscellaneous. Civilian traffic will not interrupt military traffic. When roads are closed for repair all adjacent control posts will be notified.

The rules stated are essentially those followed by the British after four years of war experience.

In the special case of an action, particularly during the early stages, an order of traffic priority may be required. The following is a good order:

Purpose of Traffic.	*Class of Traffic.*
To make the road usable	Road parties and transport.
To push the attack	Artillery and its ammunition.
	Small-arms ammunition.
	Signal-corps vehicles.
	Engineer supplies other than road material or equipment.
To evacuate wounded	Ambulances.
To feed troops	Rations and kitchens.
Ordinary supply	Other supplies.
	Baggage.

It is utterly idle to attempt to use a road before the engineers have it open for traffic, yet this error is repeatedly committed. An officer of military police, detailed as liaison agent with the division engineer, should establish traffic termini when and where the latter has the road

open and usable. At these traffic termini all traffic must either turn back or leave the road at once. Sometimes a road can be opened to 1-track width rapidly, but requires time to open for 2-track traffic. In this case passing points must be arranged for the return of empty road transport and other traffic be sent forward in sections no larger than the 2-track portions of the road will accommodate. Traffic from the front will be limited ordinarily to road transport until the road is open 2-way or made into a loop. In the case where other transport, especially ambulances, must be allowed to return from the front the following method will serve: Establish control posts at both ends of the 1-track stretch. Send transport one-way in a section about 400 yards long with a military policeman on the last vehicle. When the section passes the stretch send a section through in the opposite direction, the military policeman returning on the last vehicle.

Between 3 and 5 miles from the front will be found hostile artillery at the beginning of an attack. Unless the initial assault penetrates this zone a disastrous check may be expected. Within 25 miles of the front will be a large share, if not all, of the defender's advance supply depots, without which he loses his advantage over the attack in matters of supply and whose loss means a material setback not easily remedied. Two or three rapid drives, each of about 4 miles in depth, and following each other without intermission will generally serve with their exploitation to break through all organized lines of resistance and penetrate this zone, leaving the way clear to open warfare at least if the attack does not actually split the opposing forces. With a barrage of one shell per minute on each 8 yards of front, and proceeding at the rate of 100 yards in 8 minutes, the divisional artillery alone will require for each of these attacks in the neighborhood of 4,000 tons or about 2,000 truckloads of ammunition, the supply of which must follow as rapidly as the infantry advances if the full fruits of victory are to be gained at minimum cost. The advance of this supply of ammunition depends absolutely upon the opening of ways of communication. The commander who seeks a speedy decision that will crush the enemy without making his advance a continuous graveyard of his own army and bankrupting his nation is forced to make for his roads the fullest provision; for upon them rests the measure of victory.

Fire Facts.

Thirty-five cities, of 20,000 inhabitants and over, had a fire loss in 1918 that exceeded $5.00 per capita, the highest being Burlington, Vt., with $21.74 per capita. The average for the entire United States was: $2.42 in 1917 and $2.76 in 1918.—Extract, *Engineering News-Record.*

ENGINEER TROOPS IN AN ADVANCE.

By

Col. G. B. Pillsbury,

Engineers, U. S. A.,
Corps Engineer, 2nd Corps, A. E. F.

It is, perhaps, a matter of common observation that the expert, with long experience in some particular line of endeavor, is least qualified to write concerning the fundamental rules of his work. To him these rules are commonplaces, not worth mentioning; exceptions alone are matters of interest. For this reason the writer, with but a brief experience in an actual advance, believes that he may usefully set forth his observations; trusting the reader to observe the caution that, on account of this brief experience, some exceptions may be mistakenly set forth as general rules.

No two wars will ever be fought under the same conditions, and the lessons that we have just learned in France must be modified in their application should we ever unfortunately be drawn into another great conflict. Nevertheless, the experiences of the past must be of value in studying the military activities of the future.

ACTIVITIES OF ENGINEERS.

The war of large masses is a highly specialized form of endeavor, in which each branch of the army finds itself fully occupied with its own especial rôle. In particular, the infantry in an advance is wholly occupied in combat. The entire preoccupation of every officer and man must be, and is, turned toward gaining ground and destroying the enemy. The effort of all other branches is devoted to assisting the advance of the infantry.

We are all prepared to accept as an axiom the principle just set forth. We are, however, accustomed in normal times to see the infantry perform all varieties of odd jobs, through fatigue details of every sort; and it is sometimes difficult to realize that when the supreme effort comes all special services must stand by themselves, and be sufficient in number, condition, and physical availability to get the work done.

The principal fields of action of the engineers in an advance, as developed in the World War in France, are, briefly:

Communications—construction of roads, bridges, and light and standard railroads;
Protection against enemy mines;
Water supply;
Deliberate defenses;
Supply of engineer tools and material;
Mapping.

The successful accomplishment of work required in each of these fields depends upon the further function usually listed in the duties of engineer troops, namely, reconnaissance. I think that the duties covered by this somewhat difficult and overworked word can be made clearer, however, if reconnaissance is treated as a preliminary to specific ends, rather than an end by itself.

The division and allotment of these duties among the various classes of engineer troops, in the general British practice, is roughly:

The Division Engineers—

Provide river crossings for the infantry;
Search for enemy mines;
Open up the roads to traffic;
Construct emergency bridges;
Provide hand-pumped water supply;
Supply engineer tools and material to troops, and report captured engineer stores;
Lay out defense lines against a counter-attack, if ordered.

The Corps Engineers—

Generally coördinate the work of division engineers;
Elaborate the search for mines;
Take over and continue the improvement of roads;
Construct semi-permanent bridges over the smaller streams;
Provide water supply by power-operated machinery;
Supply material to divisional engineers;
Lay out rear defense lines, if ordered.

The Army Engineers—

Maintain general oversight over the work of Corps Engineers;
Construct bridges over large streams;
Supply engineer material to the corps;
Lay out the third line defenses, if ordered;
Disseminate information concerning enemy mine practice, geology of enemy areas, water supply, road metal, etc.;
Conduct mapping and map reproduction.

The present paper is directed to the activities of the division and corps, during the advance proper. The subject of defenses is omitted, as the writer has no practical experience in this particular.

ROADS.

The opening up and repair of roads is the duty that will absorb by far the greatest number of the engineer troops. The kind and amount of work that must be done will depend entirely on the local conditions, and the activity of the enemy in his demolitions, but the following principles are believed of general application:

First, in all warfare involving large bodies of troops, the advance will find a reasonably complete system of existing roads in the territory taken from the enemy. Without such roads there could be no enemy in sufficient force to require any great concentration of our own troops.

Second, these roads will be more or less pitted with shell holes; but except in the No Man's Land between two lines that have been stationary for some time, the shell holes will not be so numerous as to be a grave matter. It may be observed that the hard surface of a road forms an ideal burster course, and therefore the shell craters in a road are usually of moderate size.

Third, the enemy demolitions will necessarily be local in character. It is one of the paradoxes of engineering that a road, a structure rapidly destroyed by overuse or by neglect, is at the same time a structure impossible to deliberately destroy, on a wholesale scale, under the conditions of a retreat. The engineers will almost certainly find all bridges and viaducts destroyed, overhead crossings blown down on the road, and they may find a certain number of mine craters in the road; but between these obstructions the roads will be in fairly good condition.

Fourth, there will always be some obstructions—débris of houses thrown down by artillery fire, trees across the road, abandoned and destroyed vehicles; even though the enemy makes no deliberate obstructions.

The system of initiation, direction and control of the roadwork varies in different national services. The one with which the writer is familiar, and one which worked smoothly, is as follows:

The Corps Engineer receives very prompt information of a pending attack. He studies road maps and airplane photographs of the area covered by the advance. The former show roads improved before the war; the latter show the degree to which roads are now used. Between

the two it is possible to select the best system of supply roads, a system that is definitely decided on by consultation with the administrative sections of the Corps Staff. Any special requirements for the Corps Artillery are ascertained from the Corps Artillery Commander. The battle orders to the divisions prescribe that the division engineer forces will open up roads in this system specifically allotted them. Depending upon the necessities of the case, the Corps Engineer obtains from the army such road material as may be required and available; and from the administrative section of the Corps Staff secures the necessary extra trucks and wagons for the transportation of road material. This he allots to the Division Engineers and to Corps Engineer troops.

The Division Engineer, after receiving this information, is able to make his own plans. The roads selected must be opened up for the horse-drawn traffic that follow up the advance well into the zone of active shell fire—artillery, ammunition trains, and ration and water carts—and must be put in condition to bear the enormously concentrated traffic—heavy artillery, trucks with ammunition, troops, supply trains, and ambulances—which will jam the roads to utmost capacity immediately behind the zone of active shelling. After this last traffic has once come on the road, the difficulty of repair is enormously increased, on account of the interference by the traffic itself.

The work can best be accomplished, in the usual case, by having comparatively small parties, in well dispersed formation, go forward to remove minor obstructions, fill such shell craters as block the road to horse traffic, find and mark detours for such traffic around major obstructions, and send back reports of conditions; by following these by another relatively small patrol party, provided with transportation for repair material, whose duty it is to complete the filling of the shell holes and to fill new ones that may be formed; and by concentrating the remainder of the forces available for road work on the major obstructions.

Some of the details to be settled are:

What size the advance parties are to be, to whom they are to send reports and at what stage of the attack they are to move forward. As for the first, there is one general rule; detachments are to be the smallest that can fulfill their mission. If no particular difficulties are expected, one platoon or less on each road should suffice.

The advance parties report to the officer who controls the road work. The question of the best system of control is by no means definitely settled in the mind of the writer. Two are in use; one to attach the engineers to infantry regiments and brigades, but with definite mis-

sions; the other to operate by a special organization. Presuming that the brigades attack side by side, one may assign one engineer company to each infantry regiment, with its captain at regimental headquarters; the battalion commanders are stationed one at each brigade headquarters; the remaining two companies, one from each battalion, are in reserve. Each major will then be responsible for roads in his brigade sector. Reports from the advance parties go to the company commander at regimental headquarters, who takes such action as he may with the forces at his disposal, and forwards the report to his major at brigade headquarters, who can call on the second company if available, and if necessary. The major in turn sends the report to the Division Engineer. This system has many and distinct advantages. The engineers are in touch with the tactical situation, they are on established lines of liaison, and the engineer troops are immediately available for technical work required by the infantry. The disadvantages are that it often can not be put in operation from the fact that particular tasks for the engineers may not be related to tactical considerations, but to supply. Again, regimental and brigade headquarters are likely to be in a cramped locality, where the extra engineer officers and runners are in the way and are not able to function properly. Lastly, unless there is a thorough understanding on the part of the infantry commanders as to the rôle of the engineers, the latter may be frittered away on non-essential missions, or used as infantry before such last resort becomes essential, with the consequence that the roads are not ready for the advance of the corps. However, the first objection may be overcome in the initial assignment of troops—the latter two by training the engineers and infantry to work together.

The second system is to establish a forward road report center, with an officer, preferably of field rank, stationed thereat, in charge of road work in the divisional sector. Reports go to this message center, and the officer takes suitable action with the forces at his disposal. An engineer liaison officer (lieutenant) at each brigade headquarters maintains the desired liaison between the infantry and engineers. A possible disposition would be—one battalion on advance road work, with advanced parties of say three platoons out, the remainder of the battalion in local reserve near the report center; the other battalion in rear reserve, or on special missions. This system is advantageous when it is known that heavy work on a certain part of the road system is necessary. The engineers are more immediately at hand, and are less likely to be dissipated. Although probably wrong in principle, it may often be necessary to resort to it in practice.

We may next consider the stage of the attack at which the engineers will work. The road work must be done under shell fire, as it should be completed, or at least pressed as far as possible toward completion, by the time that the cessation of shell fire makes the roads available to heavy traffic. It is a mistake, however, to push any of the parties too far to the front, or too close to the advancing infantry. The writer does not believe that anything is gained by attempting to carry road-work of any kind into the zone of hostile machine-gun fire. To be sure, the reconnaissance of the roads should eventually be pushed up to our own front line of troops; but the result secured by attempting to push the work itself too far forward are not worth their cost. No transport will use a road that is under machine-gun fire—except perhaps at night after the fighting has quieted down—and it is criminal to incur loss on work that will not be utilized. Moreover, unless the engineers are very well experienced and disciplined, they are likely to join with the infantry in the fighting at critical times if they are too close to the front line, and so become lost as engineers until the immediate operations are over. Every last man of the engineers is likely to be needed for essential engineering work before that period necessitating their use as infantry is reached.

The question of how far forward the advanced road parties will press their work must depend mostly on the judgment and leadership of the officer or non-commissioned officer immediately in charge. It can, however, be regulated to a considerable degree in fixing time at which the parties start. It has been the experience of the writer that where such parties started with the infantry, the work delegated to them was often not accomplished; but when they began some hours later their mission was usually carried out.

The really critical part of the arrangements, on which success or failure depends, is the concentration of adequate engineer forces, with the necessary material, on the major obstructions. The difficulty lies in the fact that one does not know in advance where the major obstructions will be met. Some of the points where work will be required may, to be sure, be determined in advance. The work required immediately in front of the position where our front line stands before the advance as well as that behind it, is of course known, and much can be done by studying the map of the territory to be covered by the advance. Leaving the question of bridges over streams to be dealt with separately, it is usually safe to assume that the road will be blocked and considerable work required where it passes under or over a railroad. But it is the unexpected that always happens, and obstructions

whose removal requires considerable intensive effort may be encountered anywhere. The situation can be met only by having a considerable reserve of engineer troops, with reconnaissance and liaison so well organized and executed that these may be sent where required. It is well to remember that if this reserve is so far forward as to be quickly available, it will be in the zone of fairly active shell fire; and even though the place is so well selected that the losses are negligible, the troops will not be in condition for very efficient work on the second day of the attack, or even during the night of the attack. The strain is very fatiguing, even if the troops are doing nothing and suffering no real losses. In order to keep the work going with maximum efficiency, therefore, there must be fresh engineer troops held available behind the zone of fairly active shell fire.

The feature apparently the most simple, but actually the most difficult, is the reconnaissance and liaison. Nothing is simpler in theory than to have an officer or non-commissioned officer go over the road and send back to the designated center word of any important work required. From the center orders may then be sent to the necessary troops to get on the work, and information sent to higher authority, so that such further arrangements as are necessary for its most vigorous prosecution can be made. In point of fact, however, various things happen.

First. The officer or N. C. O. is under fire while making the reconnaissance, and, unless he is of very rare mental make-up is not thinking as coolly as he normally does. He is very likely to forget to report some features of essential importance.

Second. The advance may not go as expected—progress along the road is held up by an enemy machine-gun nest. The patrol leader reports conditions and waits for the situation to clear; finally sends for or comes in for further instructions and receives them from competent authority, assigning him to some other urgent and pressing duty. When the machine-gun nest is finally cleared up, and the advance resumed, no one is on hand to cover the road, and an obstruction remains for many precious hours untouched.

Third. The runner returning with the report may lose his way.

Fourth. It may not be possible to establish the center at the designated point.

Fifth. The officer to whom the report is sent acts on it, puts it aside and does not forward it for some hours. It is an unfortunate phenomenon that the higher an officer's rank, the slower he is in transmitting reports.

Sixth. The officer in charge of the reconnaissance, or the runner,

or the officer to whom the report is sent may, any one of them, become a casualty.

Seventh. The telephone wires are broken, or continuously busy, and no motor transport available so that there is no way of getting the reports back from brigade headquarters or the forward report centers.

Eighth. The officer at the report center, or the Division Engineer, becoming anxious over the lack of reports, starts out to investigate. He probably gets caught in a traffic jam, and is absent from his headquarters when the report arrives requiring immediate attention. If he has failed to leave a second thoroughly informed on the situation, delay results.

Ninth. The responsible officer, fearing the condition just described, has always remained in his headquarters, with the result that he is not sufficiently familiar with local conditions to deal with the situations that arise.

In order that reconnaissance and liaison may be successful, the following essential principles should, in the opinion of the writer, always be followed:

First. There should be an officer or intelligent N. C. O. specifically responsible for the reporting on every road or section of road. The assignment should be included in the written program of instructions. He may be referred to as patrol leader.

Second. The patrol leader should have a map, or a pencil tracing of one, on which the roads for which he is responsible are clearly marked, and the map references of easily recognized points, such as cross-roads, etc., inscribed. He should also have forms for reports, so made out as to cover all essential information, and all filled in except for the information he is to gather.

A blank for the report might be like this:

At............................

........h, 7 Oct., 1918.

To O. C. Road Report Center (X35d51),

Road from Z 10 c 51 to Z 15 b 63.

Material of surface is.............., it is (under, over) 16 feet wide, in................condition, and will carry, when repaired.............. traffic. Shell holes are................ Surplus road metal is (ample, little, none). Serious obstructions met as follows, at.....................
....
....

My party has road open for................as far as................
Enemy activity:

....

1st Lieut., 963rd Engineers.

By using such a form the element of mental preoccupation can be largely eliminated. It incidentally saves much time.

Third. The patrol leader should have a second, who is as thoroughly instructed and informed as his principal.

Fourth. The patrol leader should have two runners for each message that he sends. These men should be thoroughly informed as to the location of point to which reports will be sent (they should see it if possible as they pass out to their sector) and on the topography.

Fifth. The patrol leader and his second should keep a proper distance apart, so that both will not be caught in the same shell burst—the runners returning should do the same.

Sixth. Each officer through whom reports pass should be put on his mettle to promptly transmit them.

Seventh. Responsible officers should insist that they have motorcycles to transmit messages when the wires are not available.

Eighth. Every officer controlling operations should have a competent second, wholly in his confidence, and fully informed.

Ninth. No matter how elaborate and well worked out the system of reconnaissance and liaison may be, the division engineer should supplement it by a personal inspection made by himself.

There remains the actual execution of the work after the necessary force and materials are on the spot. This is, however, the feature that need least be feared. Engineers formed and officered like our own will usually do the work when they arrive. The writer has, however, noted the following weak points on occasions:

Lack of instruction of enlisted men in filling shell holes. In the absence of other material they were uselessly filled with soft earth. It would probably be well to have each man of the advanced parties carry a few sand bags; for tightly filled sand bags, covered with a very little road metal, will at least temporarily cure a shell hole.

Failure to organize the work in reliefs so as to obtain the maximum of concentrated effort.

Failure to exact the utmost effort of the men. It is no kindness to allow men to dawdle on work that keeps them under shell fire.

Failure to look for material in the vicinity, *e. g.*, an officer filling a mine crater failed to discover an unlimited supply of sawn railroad ties within a few hundred yards of the work, which would have made a very solid surface over the crater.

The outstanding weak points in our execution of road work lay, however, in a failure to appreciate the responsibility of the engineers for traffic. Engineers are very ready to risk their lives on the work

of preparing the roads for traffic, but are prone to neglect the measures by which the full advantage of their work will be secured. The two main features of this phase of the subject are the placing of proper direction signs on the road, and the control of traffic at obstructions.

As for signs, it should be possible to determine beforehand the cross-roads at which direction signs will be necessary, and have these signs in the first wagon that goes over the road.

As for traffic control, it should be continuously carried out by the engineers at each obstruction, until the duty is taken over by the military police. The advance party, on finding a serious obstruction, should look for the best detour around it—there almost always is one; do the necessary work in knocking down walls, cutting hedges, and cutting ramps to make this detour available to horse transport; fence off the road on each side of the obstruction and put up a sign showing it to be impassable, so as to divert traffic through the detour; and finally station a man at each end to direct traffic, and control it if the detour is a one-way passage only. When the construction detail arrives they should take over the traffic direction, and be at all times ready to pull out a truck that has become stuck and blocks the traffic.

We have so far considered the repair of existing roads. Rarely if ever will engineers be called on to construct new ones. The task of constructing a new road of any length, sufficiently substantial to take heavy traffic, in the very brief time available in an advance, is one of enormous magnitude, and will rarely if ever be attempted. A near approach to the task is the work of reconstructing the roads across No Man's Land when the lines have been stable for a long period. The writer has had no experience in this work and will not touch upon it.

There is one class of new work that may, however, be very advantageously undertaken, and that is the construction of cross-country tracks for horse transport and troops in dry weather. I have already referred to the jam of traffic that follows an advance. There is nothing that congests traffic more than slow-moving troops and horse transport. If these can be gotten off the road the situation will be much relieved. Moreover, many lives, in the aggregate, will be saved by getting them off the road, for the enemy will certainly direct his harassing shell fire on the roads.

The construction of cross-country tracks requires the exercise of good judgment and an eye for country on the part of the locator; a very little labor in construction; and an ample provision of signs. They should have frequent cross-connections with the regular roads. The proper utilization requires the coöperation of the military police; for

troops and transport are very loath to leave the paved highways. In wet weather the tracks will not be usable, and troops and transport must use the roads.

There remains the question of the taking over of the roadwork by the Corps Engineer. The simplest solution, and possibly the best to adhere to in the long run, is to have a definite line, such as a lateral road, fixed from day to day as the boundary between corps and divisional road responsibility. The difficulty rests in the fact that this line is bound to be in the very critical region of traffic concentration, where the work must be prosecuted with utmost vigor and without interruption. It must not be so far forward that corps troops can not be on the ground to cover the work behind it; and it must not be so far back that the divisional troops are taxed beyond their capacity to continue the work in front with maximum efficiency. If the transmission of reports could attain the ideal, the Corps Engineer would automatically have the data to determine this line from day to day. In actual practice, however, it will be necessary for the Corps Engineer, or his assistant, to go forward and find out the conditions in person in time to get the subdivision of work for the next day in the hands of the Divisional Engineers and the corps troops at an hour such that these may issue detailed instructions to their own subdivisions.

This system means that the Divisional Engineers are continually starting work that they never finish. Were the advance continuous it would undoubtedly get them in bad habits; for it is not human to start work under these circumstances in such a way that it is most easily and quickly finished. However, the advance will always progress by leaps, and the Division Engineers will always have the finishing of some of the tasks that they have undertaken. Moreover, bad as the practice is, I fear that it will occasionally be necessary, under the stress of circumstances, for the Corps Engineer to pull out a few companies from the divisions in order to get some pressing bit of work done.

The writer believes that the best coördination of road work would be obtained by some such system as the following:

Prior to the attack the Corps Engineer regiment establishes its headquarters somewhere on the general line of the various division headquarters, or in advance of it. All engineer reports from Division Engineers go to these headquarters. At a fixed hour, say 4:00 p. m., cyclists or runners from the divisions report there to take the instructions for the next day to the divisions. In the same way at a later hour, say 7:00 p. m., runners from each of the organizations report to their regimental headquarters, whether divisional or corps, to receive the in-

structions for their units for the next day. To secure coördination, the instructions of the Corps Engineer to all the Divisional Engineers and to the Corps Engineer units should be included in a single memorandum; likewise with the instructions of each Divisional Engineer to his organizations. The Corps Engineer never leaves corps headquarters unless his assistant is there; but one of the two is habitually on the road, or at the advanced headquarters. The corps regiment likewise always keeps one officer, competent to act, at the advanced headquarters.

The traffic control in the divisional and corps road areas is not normally under the control of the engineers, but is of much concern to them. Fundamentally, the administration section of the army staff fix such one-way traffic circuits as may be required, and determine what roads are to be limited to certain classes of traffic; but it will be occasionally necessary for the corps to fix provisional circuits in its own area. The enforcement of these regulations, control of traffic at intersections, and relief of traffic blocks caused by stalled trucks, is carried out by the military police. The engineers are, however, most intimately acquainted with the present and prospective capacity of the roads, and it is most clearly the duty of the Corps Engineer to foresee and recommend traffic circuits in his area. If at all possible, these circuits must be established, and all provisions made for their enforcement, before traffic comes on them. It is not enough that the circuits be shown on a map and the order issued. They can be enforced only if there is a military police at *every* road corner by which they can be entered.

On the American sectors, I understand that the engineers were often charged with the duty of pulling out trucks temporarily stalled, and of throwing off the road trucks that were disabled. The English rarely if ever throw a truck off the road—it is towed to its destination by the next truck ahead. On those sections of road where there are many engineers at work, it certainly is sound practice to have them pull out the trucks; and still it is as certainly better to ditch one truck than to delay several hundred for an hour or more.

Radical as it may seem, the writer believes that the most efficient results would be attained by placing the traffic police under the orders of the Corps Engineer, and making that officer responsible for the establishment of traffic circuits, subject, in all cases, to approval and revision by the administrative section of the staff.

The final transfer of the roadwork to the army is accomplished by the latter announcing, from time to time, that it is taking over the roadwork to a certain line.

BRIDGES.

The engineers must expect to find all bridges destroyed, and must be prepared for their replacement. Additional crossing must be provided for the infantry and artillery in an advance. Obviously, the Division Engineers are directly responsible to their Division Commanders for getting the infantry and artillery of their divisions over the obstruction. They secure, through the Corps Engineer, the material that must be brought up for the purpose. The Corps Engineer is responsible for the general system of communications. He assigns bridgework to the divisions, in their respective divisional sectors, or to corps troops, securing the necessary material from salvaged or captured supplies in his area, or from the army. The army undertakes work that is beyond the power of the corps to handle.

The most advanced work is the construction of foot bridges for the infantry. Their erection must usually be a matter of minutes, not hours. A number of types are available—light trestles, trussed runways, and floating bridges, consisting of a line of duckboards on cork supports, supports of kerosene cans, or very light canvas pontons, or trees felled across the river. The engineers constructing these bridges go with the assaulting waves of infantry, carrying the material with them. Their losses will be heavy. Such bridges should never be undertaken unless necessary. If a stream is readily fordable in many places it should be crossed by fording. The infantry losses will probably be less if the river is crossed by fording than if the crossing is concentrated over a comparatively few foot bridges.

The field artillery will be able to cross small streams at improvised crossings, offroads, that can be very quickly put in. The material can usually be carried on the caissons. The place of crossing is determined, on the spot, by the artillery; an engineer detachment is attached and accompanies the artillery to assist them. Large streams will have to be crossed on the ponton bridges.

There remains the replacement of the bridges on the highways. The first need is to open up traffic for horse-drawn transport, then for trucks, then for heavy artillery or tanks. It is frequently stated that in present-day warfare bridges must be made of such strength as to carry the exceptionally heavy axleloads of modern artillery and tanks. This is very true; but it is not true that all bridges must carry these loads. At least one of the main forward roads must be able to carry tanks, and all of the main forward arteries must be able to carry the heaviest artillery; but there will frequently be lateral roads that need carry nothing heavier than trucks.

The Divisional Engineers will usually—perhaps always—be able to construct a bridge at any given locality, either fixed or floating, for horse transport; they often will be able to construct small span bridges suitable for trucks and perhaps for heavy artillery. Indeed, if the bridge is not too high, and if the stream bottom is not too soft, it is merely a question of putting enough supporting timbers under the bridge to make it strong enough for nearly any kind of traffic. The powers of the Divisional Engineers are limited, it is needless to say, not by lack of ability, but by the limitations of time; for they must move on with their divisions; but there will be certain special types of heavy bridges that can be more quickly constructed by Corps Engineers, who have acquired familiarity with the type.

Ordinarily, therefore, the Divisional Engineers will be charged with the construction of bridges of the types just considered to serve the pressing needs of the situation until heavier bridges can be put in by the corps—or as the final installation on lateral roads. The case will occasionally arise, however, as at the crossing of a deep cut, when a bridge suitable for all necessary traffic can be constructed in practically the same time as a temporary makeshift suitable for the lighter traffic only. In such cases the corps will normally take over the construction from the start. In any case the Corps Engineer will give very clear instructions as to what will be expected of the Divisional Engineers at each site.

Prior to the advance, it will usually be possible to determine whether or not a ponton bridge will be required, and if so, the amount of ponton equipment necessary. This can be furnished to the respective divisions. If the stream is small, not requiring a ponton bridge, the general magnitude of the job will be known; but it will not be possible to ascertain the condition that the abutments will be in, and consequently it will not be possible to order heavy material. In such case a supply of timber and planking for emergency bridges should be brought well forward on the night before the attack.

A fundamental principle is that an emergency bridge should not, if it can possibly be avoided, be constructed in such a position as to block the construction of the heavy bridge. If the approaches are wide enough, it frequently will be possible to use half of the width for the emergency bridge, leaving the other half for the heavy bridge alongside of it. Each need be, in point of fact usually is, but wide enough for one-way traffic. Together they form a two-way passage for the great bulk of traffic. If the abutments are intact (and are found free from delayed-action mines) they will not often be wide enough for

this purpose. The decision as to siting must be left to the officer on the spot, who is unfortunately anxious to get his bridge in as quickly as possible, both to make a record and to get his detachment out of shell fire.

The actual construction will rest with the experience, skill, and adaptability of the officer in charge. Work should be continued until the bridge is made as strong as it can be made by placing extra trestles and bracing; guard-rails and hand-rails should be placed, and finally a sign put up at each end showing what kind of traffic the bridge will stand.

As has been said, there rarely will be enough data at hand, before we obtain possession of the site, to order the material for a heavy bridge. Even if the exact original span is known, the span required after the abutments are blown will not be. One of the first things to do is to get the data by which the heavy bridge material may be ordered from the army bridge park. The obvious way is to have the divisions send in a report. Unfortunately, however, the bridge site will be receiving much more than its share of shell fire, and unless very special precautions are taken the Corps Engineer will not in all probability get a prompt report sufficiently definite for his purpose. The Corps Engineer will do well, therefore, to see that the officer at the bridge has a report form with blank spaces for all information required—and he will also do well to send an officer of his own, experienced in bridge construction, with a similar form and with the sole duty of reporting the data. Under no circumstances should the ordering of the material be delayed beyond the day when site comes in our possession. It should be on the road, in trucks, that night.

ENEMY MINES.

The search for enemy mines is a very important field of engineer activity. There is first the discovery and removal of mines that have been placed but which the enemy has failed to explode. These are fairly obvious. The real task, and one whose successful accomplishment is rare, is the search for delayed-action mines. It is now, perhaps, proper to admit that delayed-action mines are much more efficient in breaking communications than are ordinary demolitions; for they often occur at points where no men are available to make the damage good. A delayed-action mine in an abutment of a bridge which has itself been destroyed is particularly efficient, even if somewhat devilish, for the explosion takes out the new bridge. The more promptly the search for delayed-action mines is begun the better, for the chances of

finding them is increased when the traces of the excavation are fresh; but the first superficial examination will not discover many that have been skillfully placed. Certainly each bridge abutment at every road and railroad should be gone over with great care, even to the stripping of the ballast for a reasonable distance back from a railroad abutment. It is, of course, unnecessary to say that the entrance to the concealed shaft by which the charge was placed will be somewhere back of the abutment and never in the masonry itself.

It is rather a question whether the best results are secured by having the search for mines executed by Divisional Engineers with the advance, or whether the work should be done by corps troops. Divisional Engineers should very clearly understand that it is always their business to be on the lookout for enemy mines and to render them harmless, if found, but I believe that when there is good reason to suspect the existence of delayed-action mines the systematic search for them is best accomplished by a special detachment of Corps Engineers continuously charged with that duty.

WATER SUPPLY.

As with enemy roads, there must be water in the area taken from the enemy and covered by the advance, or there would have been no enemy to fight. There will be cases where the supply of the conquered area comes from territory still held by the enemy; a situation that would certainly create great difficulties, and one with which the writer frankly has no experience. The problem is wholly dependent on the water resources of the country fought over, and no general procedure can apply.

The territory covered by the advance with which the writer was connected had an abundant water-bearing strata at a depth of from 50 to 200 feet below the ground surface. The first three miles of the advance was over a region long fought in, and was practically without wells. From there forward, wells, operated by windlass and bucket, were numerous. The first advance was about six miles; with the result that the horse lines in the interim before the next advance were on the forward edge of the dry zone. One large water point was here established for the corps area. The congestion at this point was extremely bad. The next advance made numerous wells available for horse watering, and thenceforth no difficulty was experienced.

The Division Engineers, in each advance, had special parties examining wells, sampling the water, putting up notice boards as to

potability and amount of chloride of lime required, and repairing windlasses and supplying rope, buckets, and horse troughs. The corps water supply service followed, installing small power pumps and horse troughs at suitable points. The system worked exceedingly well. The writer doubts whether the measure of chloride was always used, but at least any well which was positively dangerous was not used.

The details of the water supply points established may be of interest, even though they were developed to meet special conditions. In point of fact, in reviewing the work, it is apparent that the development was not really toward the actual conditions of this particular advance, but to the conditions that had preceded it, an advance over a devastated country.

A complete typical water point comprised:

A power pump, usually gasoline driven, delivering water to an overhead tank, either canvas or corrugated iron.

A set of horse troughs, of canvas or sheet iron.

Frequently a chlorinating tank for drinking water.

One or more standpipes for filling water carts and water trucks.

A stand with spigots for filling canteens.

An essential part of the installation was a plank or brick roadway to the horse troughs and standpipes.

The well supplying the water might be a dug well existing before the war, or a driven well. In the former case the pump was normally of the band elevator type—a simple canvas belt dipping into the water and running over an elevated pulley at the top of the well. Water adhering to the belt on its upward travel is squeezed off at the pulley and runs by gravity to a tank. In the latter case an air lift, operated by a compressor, was used. An ordinary suction and force-pump, of either the rotary, centrifugal or plunger type, was used in the somewhat rare cases when the water was sufficiently near the surface to make the installation simple.

Where the supply of a well was ample, one well supplied two or more water points at some distance apart. All piping was normally buried to a depth of 18 inches as a protection against shell fragments.

Air compressors for operating driven wells were usually mounted on trucks, so that they could readily be moved from point to point. In point of fact, the demands at any particular well kept the truck immobile at that point until the point was discontinued.

Generally, the water points were established at intervals of from two to three miles. The supply of drinking water for forward areas

was, in theory, by water tank trucks to advanced temporary canvas tanks.

All power-operated machinery was supplied by the army, which maintained very close supervision over the number and character of the installations. The army further supplied the corps with a limited number of sterilizing lorries, each of which was equipped with pumping machinery, a mechanical filter and a chlorinating tank. These could draw water from any stream, and deliver potable water to water carts and tank wagons at the rate of from 500 to 1,000 gallons per hour.

In point of fact the actual advance was too rapid to make the installation of any such elaborate water supply points possible. Long before they could be anything like completed, the horse transport lines had passed far beyond them. Only the simplest and readiest measures can be completed in time to be of service in such conditions.

The following weak points were noticed:

First. Not enough foresight was used in finding places for horse troughs where they would be off the road. The barnyards were uninviting places, much obstructed with rubbish; and the natural tendency was to put the troughs in the most accessible locations, close to the road. Horses waiting for their turn consequently added to traffic jams. Moreover, there is always a great deal of water spilled at a water point, and the consequent soaking of the road renders its maintenance more difficult.

Second. Not enough signs were put up. With water points properly located these signs are essential.

Third. The tendency of the corps water supply service was to put in too much of their energy in perfecting rear points, and not enough in establishing new ones.

Fourth. Reports received from the divisions on the mechanical installation of water supply points captured from the enemy were not sufficiently definite to permit the prompt ordering of machinery from the army to rehabilitate them.

The conclusions which may be drawn and which are of general application are:

First. Every effort must be made to secure a well distributed water supply service. Many small points are very much better than one large one. The congestion of horses and water carts at one large point is beyond the power of description.

Second. Horse troughs, supplied by hand-pumps, should be installed at all streams with utmost promptness, and the troops prohibited from watering horses at the stream. Otherwise the stream will soon be too

turbid to serve any purpose. It is not necessary to guard the stream. A few wire fences at the points of easy approach will suffice, provided the indicating signs to the horse troughs are enough to convince stray drivers that it is easier to go to a trough than to tear down the fence.

Third. Discipline must be perfected so that the placing of directing signs to water troughs becomes automatic.

Fourth. The water supply service of a corps should include the following:

Reconnaissance. One officer and two or three master engineers (mechanical engineers), with one motor car.

Construction. Necessary engineer troops—one company or more; officer commanding to have his headquarters at corps headquarters. This officer must also have transportation.

Maintenance. Necessary detachments of engineers—engine runners and guards—to operate the power plants established; keep troughs in repair, and control and regulate the use of the troughs and supply points. The officer in charge shall have a light delivery truck to distribute supplies and rations.

Water column. There must be a reserve of motor-tank trucks to bridge over the supply of drinking water in dry areas. In an emergency any truck can be converted into a water truck by lining the body with a canvas sheet.

STORES.

The engineer trains carry a rolling dump of all tools necessary in an advance. The supplies that can be carried are not enough, however, to be of much service.

It is needless to say that previous to the operations a well stocked engineer depot (to revert to the more appropriate pre-war term) should be established at the railhead. If the operations are successful, however, it will not be long before this source of material is left far in the rear. It can serve only for the supply of articles impossible to secure in the advanced areas.

The principal bulk supply of engineer material must come from captured or requisitioned supplies. It must be the duty of the Divisional Engineers to be always on the lookout for such supplies, and to report their location. This is not so difficult a procedure as might be thought, for such supplies, in quantity worth considering, will be found only on railroads or canals and at sidings. The engineer supply officer of the corps will immediately take possession of captured engineer depots, list the material, and be prepared to issue it as necessary. He should have trucks for that purpose.

MISCELLANEOUS DUTIES.

One duty omitted from the list is the reconnaissance for and preparation of headquarters for higher units. With our organization, the pioneer platoons of the infantry regiments should be able to look out for regimental headquarters; but the engineers will be expected to have an eye out for brigade, division, and corps headquarters, and to prepare the latter two classes for occupancy. The actual selection will, of course, be made by the commander of the unit, and will be influenced chiefly by the possibilities of wire communications, but the engineers should be able at all times to give information as to the kind and quality of accommodations available. Something will usually have to be done to improve the accommodations—the higher staffs must work in reasonably convenient and comfortable quarters. The brigade headquarters will, to be sure, usually have to put up with what they find; but division and corps headquarters will need considerable work. In a real advance little can be done in the way of protection against hostile fire. Brigade and lower headquarters will be in enemy dugouts or in cellars, while division and corps headquarters will be located back of the badly shelled zone; but all should have protection against airplane bombing as soon as it can be gotten up.

If the advance halts, or if a division is even temporarily out of the line and stationary, the engineers must get baths erected with utmost promptness. Each division will carry with it the material for portable baths, and it is merely a question of finding a suitable place for their erection near a source of water, convenient to the stations of the troops, and putting the apparatus together.

The Division Engineer will have to foresee these duties, and reserve a suitable force for their accomplishment, for as soon as the division comes out of the line the Divisional Engineers will probably be "rested" by being put to work in the rear areas, on railroads, bridges, or other duties. Provided that a reasonable provision of time is made for baths, cleaning up, and extemporizing reasonably comfortable accommodations for the men, the efficiency of the engineers for front line duty will not be impaired by suitable work at regular hours in rear areas.

There are several duties that the front line engineers should not be required to do; among them are the routine repair of back roads, burial party duty, and salvage work. The writer has never known of their being employed on such duties. In point of fact, if they are really up to their legitimate duties, they will be so occupied on these that there will be no temptation to employ them on duties that labor units can equally well perform.

MONONGAHELA RIVER NAVIGATION.

By

Lieut. Col. H. W. Stickle[1]

Engineers, U. S. A.

1. HISTORY.

The Monongahela River taps the richest bituminous coal region in the world.

The State of West Virginia alone is estimated to contain more workable coal than the whole of Great Britain. The coal mined annually in the region immediately adjacent to the Monongahela exceeds by over 60 per cent. the annual output from the four great coal fields of South Africa in normal times.

Pittsburgh's great industrial development and her prestige as a steel center are due largely to the improvement of the Monongahela by canalization. Forty-five per cent. of the coal mined in the Monongahela valley is transported to Pittsburgh's mills by water, and these mills, now engaged principally in the manufacture of war material, depend on that 45 per cent. for their continuous operation.

The river presents the very unusual case of a large tributary with much less fall per mile than has the river into which it discharges. From Fairmont, W. Va.—where it is formed by the junction of the Tygarts Valley and West Fork—to Morgantown, W. Va., 26 miles below, the fall is 2½ feet per mile; but from Lock No. 7 at New Geneva, Pa., to Pittsburgh, a distance of 83 miles, the fall is 0.7 foot per mile, while the average fall per mile between Pittsburgh and Wheeling, 90 miles, is 11½ inches—all at low-water stages. The ordinary fluctuation of the river due to floods is 20 feet and the extreme fluctuation is 35.5 feet. The river, in the first 25 miles below Fairmont, has a number of sharp bends which, with the narrowness of the stream, place a practical limit upon the size of the tows. Below Morgantown, the bed slope being small, the freshet currents are reduced in velocity and, the stream being wider, larger tows are practicable.

Before the river was canalized navigation was limited to the portion

[1] U. S. Army, Retired, District Engineer, Pittsburgh District, Pittsburgh. Printed by permission of the Engineer Society of Western Pennsylvania.

between Brownsville, 57 miles above, and the mouth of the river at Pittsburgh. At Brownsville, connection was made with the National road leading to Cumberland and the East. During high stages boats ascended as far as Morgantown and at times even to Fairmont. Large quantities of lumber were rafted downstream.

In 1836 the Monongahela Navigation Company, under charter granted by the State of Pennsylvania, commenced work on the lower river, putting the first two locks in service in 1841, and gradually extending the system upstream, completing Lock No. 7 in 1883. Locks 8 and 9 were built by the United States and completed in 1889, with the result that boats drawing five feet could navigate the river in low water as far upstream as Morgantown. After much litigation extending from 1883 to 1897 the United States acquired the franchise and all the property of the Monongahela Navigation Company, and the locks were opened to free navigation on July 7, 1897. Enjoying for the first time the entire freedom from toll charges, the commerce of the river, under the influence of prosperous times which immediately followed, increased very rapidly, creating a demand for extended lockage facilities, particularly in the five lowermost locks.

2. PROJECT.

The existing project provides for the improvement of the river by 15 locks and dams to afford slack-water navigation from Pittsburgh to four miles above Fairmont, W. Va., a distance of 130 miles. Locks 1 to 7 were acquired by the United States in 1897, and Locks 8 to 15 were built by the United States prior to 1904. Increased traffic necessitated an enlargement and improvement of the locks and dams between Pittsburgh and Rices Landing, Pa. In rebuilding locks and dams from 1 to 5, the adopted standard was two parallel chambers each 56 by 360 feet, with a depth of eight feet on sills, and fixed concrete dams with movable tops; and at No. 6, a single lock of the standard dimensions with a depth of seven feet on sills. Traffic conditions have not necessitated the rebuilding of Locks 7 to 9, which have a controlling depth of five feet on their sills. The project includes the building of Locks 10 to 15—single locks 56 by 182 feet, with a depth of seven feet on sills—and fixed concrete dams which are still adequate for the present traffic. The channel width varies from 125 feet, in pool No. 15, to 500 feet, in pool No. 1.

3. OPERATION OF LOCKS.

By means of flash-boards or adjustable tops on the dams, the safe navigable depth to Lock No. 7 is nine feet. Dams 1 and 5 are pro-

vided with Betwa wickets, and dams 2 and 3 with Chittenden drums. The Chittenden drums work satisfactorily when conditions are favorable.

Movable tops are not reliable and the only means of insuring a greater dependable depth would be to increase by three feet the height of the fixed dams. This would cause a loss of five days annually on account of the locks being flooded more frequently and for longer periods. Lockage is now possible until the water in the upper pool is 20 feet, at which elevation boats can no longer pass under the bridges, and increasing the height of the locks would result in no benefit to navigation. The double locks practically insure uninterrupted navigation through-

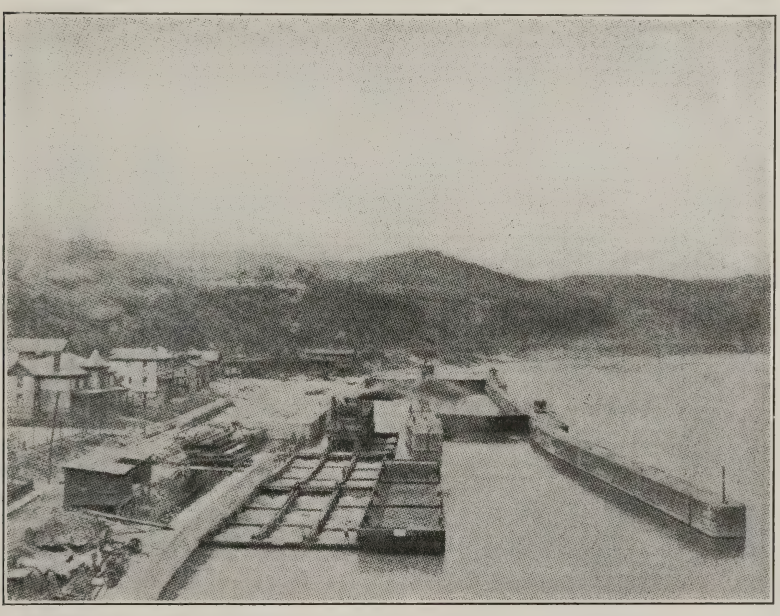


Fig. 1. Monongahela River Lock No. 4—Downstream.

out the year except an average period of five days, when the locks can not be operated on account of ice and high water.

Between Pittsburgh and Rices Landing the traffic is so incessant that the ice in the pools is kept broken up to such an extent that navigation is not altogether suspended during the winter months except in exceptionally severe winters like the past one. The delay on account of the frozen river, during the past winter, was so serious that large navigation interests immediately designed various devices to combat the ice. Floods are of short duration and do not seriously interfere with navigation.

Where practicable, dams are on solid rock and, in recent construction, of concrete. In the lower reaches the dam is of rock-filled timber-crib construction, resting on the river-bed, with upper and down stream slopes of solid timber, and with sheet-piling driven along the upper faces. The comb crests of such dams are objectionable. Ice and drift are enabled to concentrate their attacks at a single line and considerable damage has occurred requiring frequent repairs. The upper slope should be reduced to a level surface and all exposed surfaces should be of concrete, nowhere less than three feet in thickness. Scour below the cribs has occurred, endangering the dams, but failure of such dams never occurs before the partial destruction of the cribs. At Dam No. 2

Fig. 2. Monongahela River Lock No. 4—Break in Dam Closed.

is a concrete dam supported on piles with sheet-piles above and a timber crib below. A year ago this dam narrowly escaped destruction. The crib for nearly 300 feet in length was entirely destroyed; a deep scour developed and extended upward under the dam in some places to the sheet-piling above. The ability of the concrete to arch over a great distance seems to be the feature which saved the dam. The repairs to such a dam are troublesome and expensive. The new crib has a concrete top. Allegheny River Dam No. 2, which failed this month for a length of 350 feet, is of almost identical design.

In the upper dams, unless there is a rock ledge, a scour invariably develops, below, on the abutment side. Protection by riprap is neces-

sary. Constant attention to the feature of scour, and repeated replacements of iron parts in the rock construction, constitute the chief work in the maintenance of slack water on the Monongahela.

Operating Machinery.—With the exception of No. 8, all the upper locks from 7 to 15 are operated by hand. The valves and gates at Lock No. 8 are operated by power developed by 15-inch turbines—one located at each gate—which can be operated under a minimum head of three feet. The power from the turbine is transmitted through a vertical shaft, at the top of which is a worm engaged with a worm-wheel attached to a horizontal driving-shaft, on which are mounted two chain drums—one for opening and one for closing the lock-gates—and two bevel-pinions, both of which are engaged with a bevel-wheel, attached to a shaft—perpendicular to the main shaft—for raising or lowering the vertical slide-valves used for filling or emptying the lock chamber. The valve is raised and lowered by engaging either one of the bevel-pinions on the main driving-shaft, causing the bevel-wheel and its shaft to revolve in either direction, and engaging the spur pinion on the other end of this shaft in a gear rack attached to the top of the valve-rod. The valve is balanced by counterweights.

The gates, which are of the miter type, are operated by the cross-chain method, one leaf being opened by a chain attached to the toe of the gate at the bottom and on the upstream side, and the closing chain for the same leaf being attached in a similar position on the lower side, the chain leading to the lower drum on the opposite wall.

Compressed air is the motive power at all of the lower locks. The plant consists of a water turbine, connected by bevel-gears to an air-compressor. Air, at 100 pounds pressure, is piped from the reservoirs to all the engines operating the valves and gates, and for speed and economy of operation has given most excellent results. One stroke of the cylinder opens or closes one of the miter gates in 40 seconds, but in actual practice 60 seconds is considered advisable. The actual time consumed in closing the upper gates, emptying the chamber, and opening the lower gates or reversing the lock, is 4 minutes 13 seconds. The average time to lock a packet-boat is 10 minutes. The average time consumed by a single tow in entering and leaving the lock is 14 minutes. The average time in locking a double tow down and a double tow up is 1 hour and 30 minutes—16 lockings of 5,000 tons, or 90,000 tons a day, or 32,000,000 a year, so there need be no fear for some time to come as to the lower locks being unable to accommodate the traffic.

Water-supply.—The question of water-supply is of comparatively easy solution. With the aid of flash-boards or adjustable tops it is

practicable to maintain a depth of about 10 feet to near the head of the sixth pool. To maintain such a depth or to maintain even eight feet, in this stretch of the river, in case the locks were worked to their full capacity, it would be necessary to store water in the upper pools by means of flash-boards or dams of moderate height on several of the uppermost tributaries. It is estimated that a three-foot depth, stored in the pools above Lock No. 6, will furnish sufficient water for the locks if worked to their full capacity for a period of 3½ months, and it would seldom be necessary to rely solely on this stored water.

Fig. 3. Steamer *Alicia* About 400 Feet Above Alicia No. 1 Coal Dock—Right Bank.

In determining the size of the upper locks—10 to 15—the narrowness of the river for tows, the short bends, and the occasional swiftness of current, were taken into account. For a number of years coal was towed from the fourteenth pool to McKeesport—106 miles with 12 locks to pass in each direction.

The ice situation this year was about as severe in the Monongahela as ever in its history. There was a persistent gorge in pool No. 5, which could not be handled by the towboats of the river interests, and on February 11th it was decided that the District Engineer office would

make an effort to dynamite the gorge at Brownsville under the immediate supervision of Assistant Engineer Fairchild.

The lower end of the gorge began at the Bridgeport tipple ice-breakers, 0.7 mile above Lock No. 5. The ice was packed to the river-bed except in the channel, where it varied from four to six feet in thickness. Farther upstream it was found to be of greater thickness and more compact until at W. Harry Brown's cofferdam, about 2,000 feet above the Bridgeport tipple, it was packed about six feet below the river surface and piled to a depth of 4 to 12 feet above the river surface for a distance of 600 feet. This ridge of ice extended diagonally across the river and was wedged between the cofferdam and the mouth of a small creek on the opposite side of the river a short distance below. This ridge formed the key to the situation since it was of sufficient strength to stop the ice, piling against it from above, and by its position it protected the field of less compact ice below it. To break this key it was attacked from the downstream side after a channel 1,500 feet long had been blasted through the ice-pack below. After all shore ice possible had been loosened at the lower end of the gorge by ramming with the steamers *Swan* and *Slackwater,* blasting of the channel upstream through the center of the ice-pack was started. Eight holes were first disposed in a semicircle of about 300 feet in diameter, the curve being convex to the direction of the current. The holes were from 12 to 18 inches in diameter, chopped through the ice or to the river-bed where necessary, with a long chisel bar. From 10 to 12 pounds of 40 per cent. dynamite per hole were tied in weighted cement sacks, lowered through the holes and suspended under the lower surface of the ice. All eight shots were exploded simultaneously. The ice was well shattered in the areas encircled by the holes and for 10 to 20 feet above each hole. After all loose ice had floated away, the *Swan,* by ramming and then pulling with a snag hook, removed everything up to the solid breast. The same procedure was followed with successive series of holes until a channel 1,500 feet long had been cut upstream to the ridge forming the key. The number of holes was decreased from eight at the downstream end of the channel to five at the upstream end, the width correspondingly decreasing from 300 feet to 100 feet. The width was also controlled to some extent by variation in loading of the end holes of each series. A line of five holes was then laid out diagonally upstream from the opened channel to the left shore opposite the mouth of the creek, and in such a position as to cut across the downstream corner of the ice-ridge. When these holes were fired, the greater part of the ice along the left bank below them was loosened and floated out and

a slight movement of the ice-ridge was noted. A second diagonal line of holes, paralleling the first line about 300 feet farther upstream, was next fired, breaking the ridge at its juncture with the left shore. The entire ridge began to move, pivoting about its right end at the W. Harry Brown cofferdam, and was quickly followed by movement of the entire gorge above that point, which at the time extended to Fredericktown, Pa. The river, at this time, was seven feet above the crest of Dam No. 5.

Moderating weather, together with softening and sinking of the ice, due to suspended silt, had started the upper end of the gorge to move and undoubtedly contributed to the success of the undertaking. In drilling blast holes it was noted that for the upper 18 inches the ice was very hard, but below that point it was usually softened and honeycombed and filled with silt. After the final movement had started, the entire gorge passed a given point in three hours, but it disappeared so rapidly, by shattering on the dams and sinking, that practically no ice reached Pittsburgh.

An attempt was made to use blasting-powder instead of dynamite to shatter the ice, but this proved to be a failure. Five one-gallon jugs were each loaded with 10 pounds of blasting-powder and one No. 6 electric exploder. After the lead wires had been arranged in slits in the corks and sealed with soap, the jugs were suspended below the ice and the charge exploded. No appreciable shock or lifting effect was observed, probably because the action of the powder was so slow that pressure was relieved by displacement of the water.

4. ENCROACHMENTS. ACID POLLUTION.

The great industrial region in and about Pittsburgh, taken as a whole, owes its supremacy to its world-renowned manufactories, coal-mining operations and other mineral production, which render necessary the extensive railroad and water transportation systems. The narrow bottom lands suitable for the larger manufactories and for railroad and yard transportation purposes are limited in area; so that, once established, those interests are soon hard pressed for room for expansion and every available foot is extremely valuable. To move to new locations is undesirable, costly, and under existing conditions in many instances quite impracticable. Nevertheless, many manufacturing concerns have divided their plants or established new units, moving away from the original mills and factories as far as 40 or 50 miles.

When the manufacturers first occupied the river banks, they for many years engaged in filling up the lowlands to heights near to or

above the flood levels. Many of the plants had been constructed too low and were, therefore, subject to the ravages of extreme freshets. In more recent years an effort has been made to build and fill above flood heights, requiring enormous quantities of mill refuse. In this the railroads have been an important factor. In order to reduce their own losses they have taken advantage of every opportunity to raise their track levels above ordinary flood danger. Thus large interests have made efforts to preserve the streams in such manner as to readily discharge the flood waters and lessen the consequent damage to properties. The value of these operations to the community as a whole can not be overestimated.

Reverting to the river banks as nature left them, they in their neglected condition were usually grown up with trees and bushes extending over comparatively worthless, low, bottom lands far out on the bars, rendering the rivers in their unimproved condition almost useless for navigation purposes and incapable of properly carrying the flood waters. The trees and bushes collected great drift and ice-gorges, further retarding the flow at freshet stages and causing additional bar deposits. In such rivers, filled with eddies and with landings which were poor, and expensive to maintain, water transportation was uninviting.

It is believed that the filling in of the river banks to regular lines at substantial heights has accomplished more in a general way for both the interests of navigation and for flood protection than all other efforts, save the one fundamental improvement by locks and dams.

It has been contended that while a reasonable amount of bank filling may be an improvement both for navigation and flood purposes, the tendency of harbor-line establishment at Pittsburgh has been to encroach beyond reasonable limits, reducing the stream to a width insufficient for navigation purposes. The speaker believes that this contention is not well founded. Recent calculations show that a movement of the bank line from 40 to 80 feet back from the present harbor-line location in the Monongahela River at the Jones & Laughlin steel works would result in reducing the extreme flood height only 0.02 foot. There is no difficulty in choosing between (1) a wide river encouraging deposits obstructive to navigation and involving expense in their removal for the sake of a fraction of a foot in maximum flood height once in 25 or 50 years, and (2) improved navigation and channel conditions due to a more contracted river with filled banks.

"The ultimate difficulty besetting projects of river improvement

is . . . caused by the fact that its beds and banks are composed of a material that is erodible."[1]

If bank filling to the established harbor lines is non-erodible, or if it is well protected above and below water, it should be encouraged. Encroachments beyond harbor lines, except for construction of ice-breakers, and for certain classes of terminal facilities in favorable locations, are not permitted. Laws for the protection of navigable waters are sufficient to prevent improper encroachments, or deposits which limit the navigable capacity of the streams.

The pollution of the rivers of the Pittsburgh district by the dis-

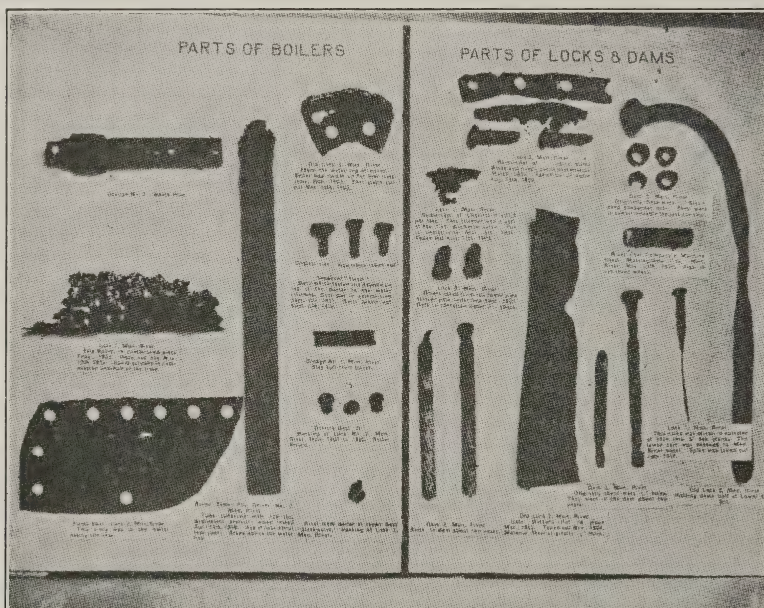


Fig. 4. Corrosion of Small Parts by Acid Water.

charge into them of acid water, and the damage to boat hulls, boilers, and the ironwork of locks and dams, have been the subject of exhaustive investigation, and many recommendations have been made. The present laws for the protection of navigable waters are not generally believed to be sufficiently inclusive to justify an attempt to prevent the discharge of acid waste in liquid form or to justify prosecutions for committed acts. This situation is on the eve of remedy since the pending river and harbor bill contains a section reading, "That, within

[1] J. L. Van Ornum's "Regulation of Rivers," p. 79. 1914. McGraw-Hill Book Co., Inc., N. Y.

limits to be prescribed by the Secretary of War, it shall not be lawful to throw, discharge, or deposit, or cause, suffer, or procure to be thrown, discharged, or deposited from any source whatever any free acid or acid waste in any form, either directly or indirectly, into any navigable water of the United States or into any tributary of any navigable water," etc. The bill provides a punishment for violation and provides the methods of enforcement.

In the lower 60 miles of the Monongahela River alone, hundreds of thousands of dollars are lost annually, by the Government, and the owners and operators of vessels, by the destructive action of acid water.

The Chief of Engineers states:

"The presence of acid and acid salts in the water results in deterioration to the boilers and hulls of steamboats, and damage to the submerged metal parts of the Government locks and dams.

"For use in boilers the water has to be subjected to a special treatment, the expense of which is considerable, and in spite of the treatment experience has shown that the life of the boilers is only about half what it should be. Formerly the boilers of vessels using these waters lasted, with average annual repair, 20 years; with similar repairs they now last only 10 years. In other words, the boilers in boats employed in commerce, and those in the boats belonging to the Government and used for purposes of improvement, must be wholly renewed once in 10 years, instead of once in 20 years.

"The damage done to the Government locks and dams is extensive. The valves, gates, plates, operating chains, and all metal parts below water are corroded and eaten away by the action of the acid. Posts have been found almost eaten through after a few years' service, when in pure water they ought to be almost as good as new. While it is difficult to fix exact money value of the damage done to these works, yet, from careful estimates, excluding as far as possible all other causes, it is safe to say that the cost to the United States of deterioration due to acid in the waters is not less than $25,000 a year on the Monongahela, and not less than $32,000 a year on the Ohio."

The proposed legislation will provide a means to stop this constant damage, and should be welcomed by all industrial and navigation interests along the river.

5. AMOUNT AND CHARACTER OF COMMERCE.

The Pittsburgh harbor commerce exceeds that of any other inland river port of the United States. For 1917, the Pittsburgh harbor tonnage was about 14,000,000 tons. At no time in the past has the traffic by water in the vicinity of Pittsburgh approached its present volume; neither has the prospect at any time for extension of water-borne commerce been so promising.

The chart (Fig. 5) shows the growth in commerce on the Monongahela River from 1845 to 1917. This commerce gradually increased, with annual fluctuations, from 250,000 tons in 1845 to 6,900,000 tons in 1900. Then it began to increase more rapidly, reaching approximately 12,700,000 tons in 1916, practically doubling in 15 years. The tonnage for 1917 is 16,000,000. In spite of the great decrease in coal shipments from the Pittsburgh district to ports along the Ohio and Mississippi Rivers, and the increased shipments by rail to meet the demands of the eastern markets, the consumption of coal in the Pittsburgh district has been so great as to show an increase in tonnage on the Monongahela River. This remarkable increase in tonnage was made notwithstanding the fact that the railroads parallel the river on

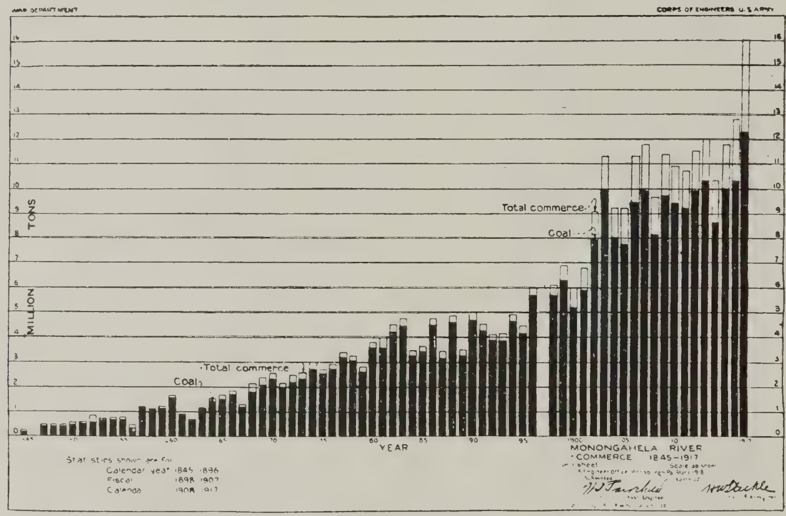


Fig. 5. Growth in Commerce on Monongahela River, 1845-1917.

both sides. Since the canalization of the river the low land has been gradually filled with waste material from the furnaces and is now used for building sites for the extension of plants or for new works. New manufacturing towns have been built along its banks, and concerns of material reputation, such as the Carnegie Steel Company, Jones & Laughlin Steel Company, American Steel & Wire Company and others producing immense quantities of raw and semi-finished materials—as pig-iron, billets, steel rails, spikes, pipe, bolts, rods, plate-glass, heavy machinery, armor plate, wire, brick, tile, chain, tools, sulphuric acid, boiler tubes, etc.—are preparing to ship by river.

To give an idea of the prospective commerce it may be stated that the by-product plant of the Carnegie Steel Company at Clairton, when

completed, will require over 8,000,000 tons of fuel a year, and this coal will be moved from the mines in the various pools by the Company's own boats which are now under construction. In addition to the shipment of coal by river, to the plant at Clariton, approximately a million tons a year of beehive coke will be handled by the Carnegie Steel Company's boats from its coke plant in the sixth pool to Monongahela Valley plants and blast-furnace plants on the Ohio River. The Company also contemplates the handling of raw material and semi-finished materials, such as pig-iron, etc.—amounting to 3,000,000 tons a year—between the various plants.

The towing of coal constitutes by far the greater part of the business of the river. The dimensions of the barges now being built by the principal firms are governed by the dimensions of the standard lock chamber—56 by 360 feet. These barges are 175 feet long and 26 feet wide and may be loaded to a draft of eight feet. Four of these barges, or three and a towboat, fill a chamber. The bulk of the coal is mined in the fourth, fifth and sixth pools and is brought down from the mines in single tows of 2,450 tons and double tows of 5,350 tons.

Formerly, at double locks, only one chamber was ordinarily in use, the other being held in reserve against accident and emergency. The tows were then made up so that each lockful had its own towboat. At present both chambers are used and each tow is made up of two lockfuls, which are sent through simultaneously if both chambers happen to be available; otherwise, in succession. One of the largest operating companies states that by double locking it saves 33 per cent. of the former cost of transportation.

The best information available is to the effect that the bulk of the coal tonnage—which has now reached over 12,000,000 tons—is moved at rates varying from one-eighth to one-half of the corresponding rail rates.

Assured of practically uninterrupted navigation, owners located steel-mills and various other industries along the river, primarily to take advantage of cheaper coal and ultimately to be in a position to ship their products by water. Some of these interests acquired coal lands, built towboats and steel barges, and installed improved unloading devices at their plants. This enabled them to materially reduce their fuel costs and insured them against a coal shortage. Certain companies have, in addition, acquired large tracts of coal lands, contracted for a large number of steel barges and towboats, and undertaken the construction of by-product plants. From Pittsburgh to Charleroi, Pa., the banks of the river are now lined with steel-mills and other manufacturing establishments.

The rich coal fields tributary to the sixth pool are now being developed. Mines have been opened; tipples have been built; and one of the largest steel concerns in the country, not slow to recognize not only the economy but the dependability in transporting coal and coke by river, has purchased immense tracts of coal land and will ship over 3,500,000 tons a year from its mines in the sixth pool. This company, heretofore, depended almost entirely on coal shipped by rail. Three concerns now control deposits of a billion tons or more in the sixth pool, and will ship by river. On account of these developments a second standard lock should be built, not because the existing lock is of insufficient capacity to do the business, but for the reason that the disablement of the lock might result in the stoppage of works giving employment to thousands of men. It is practically impossible, in this district, owing to lack of room and handling facilities, to store fuel in large quantities.

It is quite evident, if any extensive coal business is to be developed above pool 6, that Locks 7, 8, and 9 should be rebuilt, following the general design and dimensions of the lower locks. These locks are single and are only 160 by 50 feet, with a depth of five feet on the sills. With flash-boards, the depth could be increased to eight feet, but at best they could only be made available only for specially constructed barges, 160 feet long and 24 feet wide. With seven-foot draft, two of these barges would have a combined capacity of about 1,350 tons, and if a steamer had four such barges in tow the total would be 2,700 tons, requiring three lockages. Compare this with a standard lock, quite capable of passing this tonnage through in one lockage. In computing the cost of transportation on rivers, the time spent at locks is a factor of considerable importance.

Packets. For a long time the packets did a good business. Before the railroad lines were completed to Morgantown six large packets operated between there and Pittsburgh, and after the completion of the locks between Morgantown and Fairmont there was considerable business on the upper river. On account of mismanagement, railroad competition and other causes, the packet business gradually declined and finally the *Valley Gem* while in the possession of the United States marshal made a run on the bank and was frozen out of the game by the ice-gorge at Morgantown, W. Va., on February 9, 1918.

6. TERMINALS.

The advantage of lower freight rates by water, as compared with railways, will not alone satisfy the demands of modern business. At

several landings the packet companies had wharf-boats, but it was a frequent occurrence to unload valuable freight on the banks, where it was liable to be stolen, or destroyed by high water. Care of valuable goods is an important factor in the cost of transportation, and if the packet trade is to be profitably revived it must be operated under modern business methods. River terminals for freight must be provided at prominent landings and these must be in all respects equal to the railway terminals—weather-proof and accessible at all times to wagons and motor trucks. With this done along the river the cost of actual movement between given points, if cheaper by river than by rail, will be sure to attract the attention of the business man, and a fair share of general business will seek the river.

For a very extensive business at river terminals, especially where freight must be transferred from boats to railroads for points in the interior, proper track arrangement must be provided. The railroads reach all parts of the interior, and it is a matter of great concern to the general shipper that equitable and legal arrangements be made for interchange of traffic between the river and the railways.

The present method of appropriation for river and harbor improvement is a development from what could, not inappropriately, be designated a "pork-barrel" method, when congressmen exchanged courtesies in voting money for various districts. At present, however, no project will be considered for appropriation unless it has the recommendation of the Board of Engineers for Rivers and Harbors, so, no matter what other criticism may properly fall upon appropriations for river improvement, the cry of "pork" is unjustified. For the past few years great emphasis has been placed upon the question of terminal facilities. In the pending river and harbor bill appears the following:

"The Secretary of War is hereby requested to investigate and submit to Congress on or before the first Monday in December, nineteen hundred and eighteen, a report showing (*a*) the status of water terminals at cities and towns along the Ohio River between Pittsburgh and Cairo, inclusive, and whether owned by municipalities or some other public agency, and whether the same are satisfactory as to location, construction, and equipment; (*b*) the names of cities and towns where an interchange of traffic exists between the water transportation lines and the railroads; (*c*) a list of the water transportation lines existing and proposed on the Ohio River with a description of the number and type of boats in operation and under construction or to be constructed and as to whether the same are appropriate and suitable for the traffic; (*d*) the names of cities and towns where no adequate public terminals exist, together with a statement of any prospective plans for

water terminals and the status of same; (*e*) any recommendation for the development of transportation on such river."

This is probably a step in the right direction, but in my humble opinion they have the cart before the horse as far as the Ohio River is concerned. The Ohio can never amount to much until it becomes a dependable river, not only for 50 or 100 miles but for the entire distance from Pittsburgh to its junction with the Mississippi. Municipalities and private individuals will construct terminals only when they can definitely figure a reasonable return on the investment. They are going to have no sentimental hysteria about the sacred importance of terminals on an unused river. Some day there will be needed a capacious and modern terminal development to transfer freight from river to rail for the East, and *vice versa.* This is essential for a reasonably full fruition of the Ohio improvement. Who supposes the railroads will experience a change of heart, and dig into their pockets to pay for such a terminal? What boat line would consider such an investment in view of the lack of law to keep the railroads in line? What private individual can see anything in this for him? Such a terminal development, coupled with proper railroad laws, is river improvement just as much as dam construction, and dredging; yet the United States has not adopted any policy for terminal construction, and no such policy is in view. The trouble with the Ohio River is that the improvement is uncompleted and will remain uncompleted for many years, under the present system of comparatively small annual appropriations.

The present Ohio River project was initiated by the act of March 3, 1879, which made appropriation for the Davis Island Dam. That was 39 years ago and, due solely to lack of appropriation, the project is yet far from being completed. Imagine any corporation adopting a plan of improvement for any purpose and dragging the allotments out in such a fashion!

The *Pittsburgh Dispatch* of February 4, 1918, contained an editorial, entitled "The Ohio Appropriation," which well expresses the situation as to river terminals; having under consideration the alleged suspension of action by the Rivers and Harbors Committee while awaiting information as to what the people were willing to do toward providing terminals. This editorial reads in part:

"Yet, while it is unreasonable to blame the river towns for failing to provide terminals for a traffic possible only after the Government has completed the improvement, the committee is right in warning valley communities that the Government should not be asked to put millions into rivers that will not be properly used. A definite program should be

undertaken to assure that when the Ohio is canalized the river communities will be in shape to utilize it immediately, not by the primitive wharf-boat and landing methods, but by the most modern means, capable of loading and unloading bulk rather than packages, and providing prompt transfer where necessary to or from the rails. Unfortunately, many places have permitted their wharfage to be alienated, but most towns have enough left, or that may be recovered, for the construction of modern terminals. If the committee's action stimulates public interest in planning for such facilities, to be ready as soon as the river is completed, it will be a good thing."

7. RAILROAD COMPETITION.

The commerce on the Monongahela has increased by bounds, in spite of the fact that its course is paralleled by railroads on either side. It is estimated that there is, on the average, a saving of 35 cents on a ton of coal as compared with transportation by rail. This would mean a saving to somebody of $4,200,000 in 1917, which would more than replace every lock and dam on the Monongahela every three years, after deducting operating and maintenance charges. The value of this improvement is therefore unchallenged. This is a special condition and most river improvements in this country could not stand a close mathematical test so well.

Rail rates are evidently so made that traffic which might want to use waterways finds the rail route cheaper in the long run. Rates to and along competitive waterways are kept low, and railroads are enabled to keep most of the traffic, and make it up by higher rates to interior points. Exact comparative rates bearing on this matter are to be found in an address by Senator Ransdell in the United States Senate on September 29, 1917.[1] Rates are invariably much higher to inland points—in some instances more than three times as much. This situation is the prime reason why commerce on the rivers can not hold its own. Eliminate this evil—which is manifestly unfair to the interior points but which constitutes for communities on navigable waterways an arbitrary rail rebate—and the strategic advantage which waterway communities have by virtue of their location would naturally manifest itself. If rates per mile to interior points were to be made the same as for equal distances between river points, the railroad experts would certainly scream; but why should not railroad rates be based upon mileage, class, carload lots or less, and terminal charges, and be kept independent of extraneous matters such as competition with rates by water? The improvement of rivers in this country has

[1] Congressional Record, Sept. 29, 1917, v. 55, pp. 8236–8248.

been justified by the reduction of freight rates on railroads, and every river lock is a monument to this fact; but why should rivers be improved for any such purpose? The same effect would be produced by a legislative enactment of great simplicity.

Hon. James A. Frear submitted a minority report on the pending river and harbor appropriation bill, which is published in House Report 350, part 2, Sixty-fifth Congress, second session. This report attacks the bill generally, but contains some concise statements of interest on this subject. He says (page 14):

"Constructive efforts to promote commerce on our inland waterways involves fixing railway rates to prevent roads from underbidding water transportation companies on heavy bulk freight.

"Improved terminals, modern devices for loading and unloading, coördination of railways and waterway traffic, both physically and through joint rates, are all desirable, but are more ornamental than useful under existing conditions. . . .

"A first requirement is to control railroad rates so waterway traffic can live. Without that change in transportation conditions, failure is inevitable."

The speaker is in full agreement with the quoted statements.

8. THE MONONGAHELA AS A WAR FACTOR.

Last summer the repairs and maintenance of the lower six locks and dams on the Monongahela were declared to be important for purposes of national defense, thus placing this work in the same class as shipbuilding and cantonment construction.

Germany long since knew that improved waterways were vital for purposes of war. Thus we see canal construction and river and harbor improvement going on there, at this time, under substantial appropriations. Both railroad and water rates and the commodities each system must carry are there determined after the closest study for the benefit of the country as a whole, and not with the prime object of assuring substantial dividends for watered railroad stock.

The Monongahela is unique in its present usefulness. I know of no other interior stream in this country which is giving the same direct defense and service in this war. With its peculiar situation the Monongahela is doing its part, but throughout the United States—due to uncompleted projects on account of lack of funds; due to lack of terminals; and due to unfair railroad rates—the waterways have not given their fullest and much needed contribution to the transportation requirements of the war.

This is a war fundamentally of transportation, and improved and fully used waterways would have been worth billions to us had they been available. But they were not ready and are not in use. Consequently, to save money for the immediate purposes of the war, the river and harbor bill is pruned to the quick. If the war were sure to be terminated within the next year, this would probably be good policy, but, if a man had neglected to roof his house until the rains set in and he had no reason to doubt but that the rain might continue for 5, 10, or 15 years; if he were a man of intelligence he would proceed to get some kind of a roof on his house regardless of the difficulty and expense connected with the undertaking, and would still be happy if the sun should happen to shine the next day after completion.

The Pittsburgh district is doing its full share in the conduct of the war. How much its industrial activities—gigantic as they have been the past year—would have been accelerated had a usable canal been in operation for the transportation of ore, coal, and other materials between Pittsburgh and Lake Erie!

All the difficulties in the way of water transportation will eventually be removed. I am confident of that. We will come to realize that movement of heavy commodities by water is an economic necessity and that water transportation routes are a vital necessity in time of war, and indeed a potent insurance against war. Our millions will be devoted to preparedness against war and our billions, and a million lives, will be saved.

Plan to Finance Federal Purchase of Railroads.

A plan proposed by Senator Albert B. Cummins and modified by Mr. Gustav Lindenthal, consulting engineer, New York, is as follows:

Create a sinking fund nucleus of $500,000,000 by gradual sale, as needed, of 3 per cent tax-free 10-year convertible bonds at par. The proceeds or the bonds themselves to be used for the gradual buying up in the open market of railroad securities, stocks and bonds. The interest and dividends from them to be used for interest on the Government bonds and the balance of the income to be added to the sinking fund.

As the railroads need about $1,000,000,000 annually for several years, to pay for necessary improvements and additions, the Government is to make loans to the several railroads also in the form of 3 per cent tax-free 10-year convertible bonds at par, but only after such improvements from time to time have been made.

The railroads are to be allowed to earn a surplus of at least ½ per cent above the requirements for dividends and interest, including that on said tax-free 3 per cent Government bonds. This surplus to be added to the sinking fund.—Extract, *Engineering News-Record.*

PROPOSED NEW ENGINEER SCHOOL AND POST AND COLLEGE OF MILITARY RESEARCH AT CAMP HUMPHREYS, VA.

By

Lt. Col. W. H. Lanagan,
Engineers, U. S. A.

The study of the tentative project for the "New Engineer School and Post and College of Military Research" at Camp Humphreys, Virginia, has been based upon four fundamental considerations, viz,

(1) The necessity for an Engineer School, including under this head all of the various schools required for the technical and military training of officers (Regular, Reserve, and National Guard), and for the vocational and military training of enlisted men.

(2) The desirability of establishing on the same reservation a permanent engineer post for a sufficient number of troops to ensure the adequate practical application of the theoretical principles of military art and military engineering taught in the schools.

(3) The desirability of including, as an integral part of the project, an institution under the direct control of the General Staff, to be devoted to research work along all lines of military progress.

(4) The availability of the Camp Humphreys reservation for the development of such a combination of educational institutions in a manner that will ensure that each will function at the highest possible efficiency and that the work of the three will be properly coördinated.

HISTORY OF THE PROJECT.

Preliminary studies for the development of the project were undertaken in the fall of 1918 by Maj. H. E. Kebbon, Engineers, under the personal supervision of the Secretary of War and the Chief of Engineers.

After the approval of the preliminary plan, the Chief of Engineers, in January, 1919, directed Col. Richard Park, Corps of Engineers, to prepare detailed plans and estimates, and on May 27th, 1919, a preliminary report was submitted which included plans for all buildings and all necessary utilities, with detailed estimates of the cost of con-

struction of each. Photographic reproductions of the more important plans were attached to the preliminary report.

A final report is being prepared which will go into much more detail than the preliminary report, but will not differ from it in any essential particular.

The purpose of this article is to outline the reasons for the authorization of the project and to show its general character.

NECESSITY FOR AN ENGINEER SCHOOL.

The need for special training in the Engineer Corps, for both officers and men, has long been recognized but inadequately provided for, considering the ever-broadening field of its activities and responsibilities.

The Engineer School of Application, established at Washington Barracks in 1902 for the training of engineer officers of the Regular Army in civil, mechanical, and electrical engineering, as well as in military art and military engineering, was entirely inadequate even before the war. Its laboratory facilities compared unfavorably with those of even the poorer civilian technical institutions; much of its instruction had to be confined to pure theory, owing to the lack of means of application, and its capacity was so small that less than half of the 505 officers authorized in the Corps of Engineers had completed the course before the war. This school was in practically the same condition in 1916 as when it was established in 1902; the progress made in civilian technical institutions during the same period is indicated by the records of three typical schools, viz, the University of Illinois, the Massachusetts Institute of Technology, and the Rensselaer Polytechnic Institute—given in the Mann Report on Engineering Education, published in 1918, as follows:

	1900.	1916.
Number of students....	2,451,000	13,451,000
Annual revenue	880,632	3,251,000
No. of students............................	3,184	7,884

(NOTE.—The figures given are the totals for the three institutions.) These figures are typical of the technical institutions of the country, the value of whose buildings, equipment, and expenditures has increased much more rapidly than the number of students.

The transfer to the General Staff College of the Post of Washington Barracks in June, 1919, deprived the Corps of Engineers of even this school, and forced the establishment of a temporary school at Camp Humphreys, which has excellent natural facilities for practical instruc-

tion in military art and military engineering, but inadequate and poorly housed laboratory facilities for technical training; the quarters are largely confined to those of the standard cantonment type, which were entirely satisfactory during the period of the war but make no provision for the families of married officers and are entirely unsuited for occupation over extended periods in peace time, either by married or bachelor officers.

There is therefore a present and urgent need for an Engineer School that, in addition to the military training, will provide the engineer officer with a theoretical and practical training in engineering, at least the equivalent of the training given by the typical civilian technical institutions of the country, and there is also a need for quarters that will enable the officers to maintain the standard of living that has always obtained in the Army under peace conditions. These necessities are not contingent upon an increase in the officer personnel of the Corps of Engineers, but are indispensable to the proper functioning of the Corps at its present authorized strength.

Vocational schools for the training of enlisted men have been in existence at Washington Barracks for years, but they have operated on a small scale and their purpose has been the training of men to perform certain essential military functions, rather than the broad vocational training of all engineer soldiers. During the war the enormous demand for skilled men necessitated the expansion of the vocational schools at Washington Barracks and the establishment at Camp Humphreys of similar schools on a much larger scale. A list of the special services for which units were trained and organized by the Engineer Corps during the war will give some idea of the field that had to be covered by the vocational schools:

Camouflage;
Clerical;
Crane operating and maintenance;
Electrical and mechanical (construction and operation);
Forestry (sawmill);
Forestry (auxiliary, road, camp, and bridge);
General construction;
Inland waterways, operation of boats;
Mining;
Ponton service;
Quarrying;
Railway construction;
Railway locomotive repair;
Railway maintenance of equipment;
Railway maintenance of way;
Railway miscellaneous trades and storekeepers;
Railway operation and shop;
Railway transportation;
Road building;
Searchlight service;
Sound and flash ranging;
Stevedore service;
Supply and shop;
Surveying, printing, military mapping and map reproduction;
Water supply, construction and operation.

These were in addition to the recognized duties of the sapper or combatant engineer troops, of which every division and every army corps had one regiment. On November 11th, 1918, there were 174,000 engineer troops in France; about half of them were combatant troops and half technical troops of the special service.

During peace times, it is neither practicable nor necessary to maintain the various special service units; these are called into being in an emergency. On a peace basis engineer troops are confined to the sappers, foot and mounted, and their trains; these sapper or combatant organizations should, however, be so organized and trained that they can furnish skilled specialists to form the nuclei of the numerous special services required in time of emergency.

In addition to the regular establishment, the reserve engineer troops, which will make up the bulk of the engineer forces in time of emergency, should be so organized and trained that they can expand the nuclei of both the combatant and special services to war strength in the shortest possible time and with the least possible confusion. The training of all these troops, both regular and reserve, should be carried on with a view to offsetting the economic loss due to the withdrawal of large numbers of skilled men from the trades for training, and also with a view to ensuring the individual against loss of earning capacity by reason of military service. This can be done by establishing, as an integral part of the system of training for engineer troops, an educational institution designed on generous lines, to give enlisted men diversified courses of instruction, including general education, civilian trades, the sciences, and military subjects. Such an institution would ensure every engineer soldier an education during his term of military service that would qualify him, upon his return to civil life, to earn more money and to discharge his duties as a citizen in a more intelligent manner. The man with mechanical skill, but lacking in common education, could increase his knowledge of his own trade, learn its application to military needs, and at the same time acquire the schooling in language, mathematics, history, geography, and civil government which in civilian pursuits is only acquired by the workmen of unusual ambition and energy. The boy of grammar or high school education could continue his general education and at the same time have his choice of training in one or more of a large number of trades—a combination of opportunities very rare in civil life except to those of considerable means.

The first step in the making of a good soldier is to make a good citizen. The time spent on the educational program outlined above,

far from interfering with the soldier's military training, would be of immense advantage to it, in that it would make him a better citizen and at the same time lend variety and interest to his daily work. An attempt to carry on in time of peace an intensive program of purely military training, similar to that of the war period, would probably be disastrous to morale, because of the lack of vital incentive. Half a day devoted to military and engineer drill and physical exercises, and half to school work, with the evening free for study and recreation, would probably be an effective program.

The money spent on the training of men under such a system, instead of being a total loss chargeable to military preparedness, would be returned many times over in the increased earning power of the men and the increased standards of physique, education, healthful living, and citizenship.

In the case of the engineer soldier, all of the training in civilian trades has its full effect in increasing his usefulness as a soldier. The more important vocations included would be:

Blacksmithing;	Automobiles;	Rigging;
Carpentry;	Lithography;	Stenography;
Drafting;	Steam engines;	Oxy-acetylene welding;
Surveying;	Masonry;	Machine-shop work;
Electricity;	Photography;	Railway operation;
Gas engines;	Plumbing;	Camouflage.

Every man trained in one of these branches will be needed in a definite place in the engineer service in time of emergency; and yet there is no portion of the training that the man can not put to profitable use after leaving the service—with the possible exception of camouflage, and even this will include instruction in mechanical processes and in the use of paints and materials that will be of use in many civilian pursuits.

The education of the public to a realization of the benefits to be derived from a system of military training that is primarily educational along useful civilian lines, would result in attracting a superior class of men to the permanent establishment and in maintaining the morale of the establishment at a high level.

TRAINING OF OFFICERS.

Officers for whom special training in engineering is needed may be divided into three general classes:

(*a*) Regular army officers of the Corps of Engineers;
(*b*) Reserve and national guard officers of engineers;
(*c*) Line officers of combatant branches other than engineers.

(*a*) *Regular Army Engineer Officers.*

Officers of the Corps of Engineers have two distinct functions: one purely military, covering fortifications and military construction and operations, including the training and handling of engineer troops; the other, almost purely technical in a civilian sense, covering the engineering work connected with such public works as river and harbor improvements, lighthouses, and other projects of an engineering nature. Each of these functions requires a high degree of technical training, which it is neither practicable nor desirable to give at the Military Academy.

The military phase of the work requires not merely a knowledge of current military engineering practice, but also a thorough grasp of engineering principles upon which such practice is based, in order that proper methods of training may be evolved and research work carried on which will ensure the application to the military service of all new developments along engineering and scientific lines. The enormous advance during the late war in the use of mechanical devices, both in actual combat and in the numerous technical auxiliary services, has greatly broadened the field which the military engineer officer is called upon to cover. Upon the regular officers of the Corps of Engineers falls the responsibility for keeping up-to-date the engineering practice of the Army and for the training of a large number of reserve officers who must be competent to put into effect, at short notice and on a large scale, the policy and methods established by the regular officers.

The public engineering work with which the Corps of Engineers is charged covers a very broad field and throws upon the engineer officer the same responsibilities as those carried by the foremost civilian engineers of the country. His training as an engineer should therefore equal if not exceed that given by the best civilian technical institutions; the civilian engineer usually specializes along some comparatively narrow line of work, as electrical engineering, sanitary engineering, hydraulic engineering, whereas the engineer officer may be called upon to solve problems in any of the numerous branches of engineering practice. The interests of the public whom he serves will be best safeguarded by providing him with the best possible mental equipment for his work; the placing of responsibility for huge expenditures of public moneys on inadequately trained men will eventually cost more than the adequate training of the men. Special training is particularly needed along the lines of organization, administration, and the economics of engineering, since much of the engineer officer's work consists of the administration of engineering projects, the details of which are handled by civilian engineers.

(b) *Reserve and National Guard Officers of Engineers.*

In order to give permanence to the training policy adopted before the war, which resulted in the expansion of the Corps of Engineers from 505 officers, in the spring of 1917, to 12,000 in November, 1918, it will be necessary to provide extensive training facilities for reserve and national guard officers of engineers, in order that they may be able, at short notice, to turn their engineering ability to the most effective use in the Army in case of emergency. Upon the basis of twenty years' useful service for the average reserve and national guard officer, 600 should be trained annually in order to maintain a reserve of 10,000 officers, which is somewhat smaller than the total number commissioned during the war.

The training required for these officers differs radically from that of the regular officer, since they will be called upon only for active service in the field and their function will be the transmission to the Army of the military engineering practice evolved by the regular officers. The advantage of maintaining the reserve at its present strength by training a few hundred officers each year, instead of training several thousand within a few months, is obvious. The civilian engineer who receives, at the outset of his professional career, a thorough training in the fundamentals of military engineering, will keep in mind thereafter the possible application of his own experience and that of his branch of the profession, to the needs of the military service, and will on this account be much more efficient than the civilian engineer who is called from his work in later years to receive his first training in military work. Probably the ideal reserve officer would be one who, during his four years in a technical college, would spend six months as a soldier in a training camp, under either a voluntary or universal system of service, and within a year or two of his graduation would spend one year as a selected student in the Engineer School, studying the theory of military art and military engineering and at the same time putting this theory into practice, with regular troops under field conditions. His training thereafter could be kept up-to-date by service in the national guard of his State, by correspondence schools administered from the Engineer School and by occasional short periods of active service. In this manner he would, with no loss to himself, be in constant touch with the policy and methods of the Regular Army and would be ready at any time to enter upon active service and give effective aid in putting such policy into effect.

(*c*) *Line Officers of Other Combatant Branches.*

It is essential that officers of all combatant branches should receive training in certain branches of engineering work, such as the construction, maintenance and repair of roads, hasty entrenchments, river crossing expedients, and map reading, since troops of all combatant branches must be trained along these lines. The function of engineer troops in warfare is not the performance of manual labor involved in the construction of engineering works; their numbers, 1,650 in a division of 27,000, are utterly inadequate for such a purpose; their proper function is the direction and coördination of engineer work, rather than its actual performance, most of which is done by troops of the other combatant branches.

In order that the engineering practice of the Army may be standardized and also that it may be up-to-date throughout the service, it is essential that all instructions originate with the Corps of Engineers.

TRAINING OF ENLISTED MEN.

The enlisted men of the Engineer Corps may be divided into several classes, for each of which a different scheme of training is needed, viz,

(*a*) *The skilled specialists who make the Army their career and attain the grade of master engineer.* Eighteen of them are required for each sapper regiment and large numbers are required by the special services. They must, of course, be first-class soldiers as well as mechanical specialists. The permanent *cadre* of instructors in the vocational schools will be drawn largely from these men, and their numbers must be sufficient to handle the work of instruction and furnish the quota of the engineer organizations maintained in peace times throughout the country. Selected men from the entire engineer service should be given the opportunity to qualify for the grade of master engineer.

(*b*) *Non-commissioned officers under the grade of master engineer.* These men need vocational training in order to fit them for the performance of essential engineer functions of a military nature and at the same time increase their usefulness in civil life, and, in addition to this, thorough training along military lines—infantry and engineer drill, physical drill, administration and paper work, supply and discipline. The non-commissioned officers form the backbone of the engineers, as they do of the other branches of the service. Even the most efficient officers are unable to function properly without thoroughly trained non-commissioned officers. A special branch of the school is therefore needed to train selected men in the duties of non-commissioned officers.

(*c*) *Privates of the regular establishment.* These men who enlist for a period of years should be given every opportunity for advancement, so that their own skill, aptitude for learning, ambition, energy, and capacity for handling men, will determine whether they remain privates or advance to the non-commissioned grades or even to the school for commissioned officers of the regular establishment and the reserve.

(*d*) *The enlisted personnel of the reserve.* This may be made up of volunteers who present themselves for a few months' training in order to qualify for military service and at the same time avail themselves of the educational opportunities accruing therefrom, or of a selected portion of the entire number of men who come of military age and who are called for training under some system of universal military service. The military training of these men will naturally be confined to the fundamentals, and will differ radically from that of the men of the regular establishment; their vocational training must be so directed as to increase their military usefulness and also their earning power upon return to civil life.

The schools will naturally have to start on rather a small scale and later expand to meet the requirements of the situation as it develops.

NEED FOR ENGINEER POST.

Camp Humphreys now has facilities for housing about 30,000 men; the buildings are of the standard cantonment type and are suitable only for temporary occupation, during training of a few months' duration, or during the mobilization of a division for maneuvers. For the housing of regular army troops who enlist for a period of years, modern barracks are indispensable.

The time spent in theoretical instruction of officers in military art and military engineering is largely wasted unless they are given the opportunity to apply the principles learned to the actual command, administration, and supply of real troops under conditions approximating those of field service. A considerable body of engineer troops of the Regular Army, representing both the sappers and the special services, should therefore he maintained upon the same reservation with the school. These troops should be models of their kind, chosen for demonstrated efficiency, and well officered. It is considered that two regiments, one of sappers and the other made up of detachments from the various special services—a total of about 3,500 men and officers—is needed for this purpose.

NEED FOR A COLLEGE OF MILITARY RESEARCH.

In order to keep the Army abreast of scientific developments, constant research will be necessary, not only by the scientists of the Army, but also by the closest coöperation and affiliation with civilian institutions of research and with other educational agencies. The late war has demonstrated the vital necessity of close and constant study of the industrial establishments of the nation, with a view to their conversion to military needs in case of emergency.

Such an institution has no direct connection with the Corps of Engineers, but in the interests of economy it may well be developed on the Camp Humphreys reservation in order to avoid the extra expense incident to its construction elsewhere as an independent institution.

AVAILABILITY OF CAMP HUMPHREYS RESERVATION.

In order to enable an institution of the kind under consideration to function at maximum efficiency, it should be situated upon a reservation that possesses the following qualifications:

(*a*) An extensive terrain of varied character for the carrying out of field engineering work and maneuvers on a large scale and under varied conditions.

(*b*) Topography suitable for building construction without undue expense for grading and roads; and accessibility to labor and material markets that will reduce construction costs to a minimum.

(*c*) Situation within easy reach of the city of Washington in order to facilitate close supervision of all its activities by the General Staff and the Chief of Engineers, and yet at a distance sufficient to make it an independent community that can develop its own individuality.

(*d*) Accessibility to sheltered water, for instruction in boating, floating bridges, and hydrographic surveying.

(*e*) A climate that is healthful, variable, and sufficiently mild to allow field work to be carried on throughout the year without serious interruptions.

(*f*) Accessibility to important engineering projects, rivers and harbors, coast fortifications, and manufacturing plants, in order that visits of inspection may be made at small cost and without loss of time.

Analysis of the conditions obtaining on the Camp Humphreys reservation shows that they conform in all essential particulars to those outlined above.

(*a*) The reservation comprises 6,400 acres, or 10 square miles, all in one tract; this is already the property of the Government and was purchased at a reasonable cost.

The terrain is quite varied in character. The present camp occupies the flat ground along the axis of the Belvoir peninsula. The southern

extremity of the reservation is the site considered the most favorable for the new project. The central parade ground of the present camp, nearly a thousand feet wide and ten thousand feet long, provides ample level space for close-order drill. The rolling ground to the north and west, with its scattered timber areas, small ravines, and wide creek valleys, is unusually well adapted to the development of field problems, from reconnaissance and patrols by squad to maneuvers by a division. Roads of all kinds can be built, demolished and repaired; sites for temporary bridges and timber for constructing them are plentiful; good camp sites are available; field entrenchments, shelters, and entanglements can be built under a wide range of conditions; mining and demolition work can be carried on without danger; a large target-range has already been established on the west side of the reservation; areas are available for the use of gas on a considerable scale. In short, there is not a feature of the combatant activities of engineer troops that cannot be practiced on the reservation on a large scale and under conditions approximating those of actual warfare. This has been fully demonstrated by the experience of several months in training engineer troops and officers during the war.

For the special services, a standard-gauge railway, built from Accotink, on the R., F. & P., to camp, a distance of 5 miles, and 20 miles of 60-centimeter (about 2 feet) gauge light railway, used for distribution about the camp, furnish the best of facilities for the training of troops in building and operating railroads. Ample areas are available for searchlight parks, rigging schools, sound and flash ranging, and other field activities. Permanent housing for the vocational schools requiring extensive mechanical apparatus is needed, and this is provided in the new project.

(*b*) The southern portion of the Belvoir peninsula, upon which it is proposed to develop the project, consists of a slightly rolling plateau about 150 feet above the level of the Potomac River. The clearing and grading necessary do not present any great difficulties and do not involve the moving of large quantities of earth. Labor is as cheap as at any other point in the vicinity of Washington. Material may be delivered by both standard-gauge railroad and by water, and distributed over the job by the light railway equipment of which there is an ample supply on hand.

Building costs per cubic foot will run from two to three times the pre-war costs for the same class of work, but will be as reasonable in this locality as in any other. Gravel and sand for concrete are available in large quantities on the peninsula, and can be washed and delivered


Lewinsville
Chain Bridge
Reservoir
WASHINGTON
Reservoir
Georgetown
Spout Run
Rosslyn
ALEXANDRIA
Falls Church
Four Mile Run
Fort Myer
Arlington
National Cemetery
FAIRFAX
Arlington
Arlington Sta.
Holmes Run
ANACOSTIA RIVER
Annandale
Run
Lincolnia
B. & O. R. R.
Oxen Run
ALEXANDRIA
Cameron Run
Seminary Sta.
Springfield
Franconia
HIGHWAY
Accotink Cr.
Pohick Cr.
Long Branch
Little
Dogue Cr.
North Branch
Broad Cr.
Hunting Creek
Accotink-Sta.
CONCRETE
CAMP A. A. HUMPHREYS
Pohick
Accotink
Mt. Vernon
Lorton
Piscataway Cr.
POTOMAC RIVER
POHICK BAY
Accotink Bay
Gunston Cove
SCALE OF MILES
0 1 2 3 4 5

Fig. 1.

more cheaply than they can be bought in the open market. There is a large clay bank from which excellent brick can be manufactured and at a considerable reduction from market prices.

(*c*) A concrete highway, 11 miles long, connects the camp with Alexandria, and the drive to Washington can be made in from forty-five minutes to one hour. A 5-mile standard-gauge railroad connects the warehouses of the camp with the main line of the R., F. & P. at Accotink Station. The electric line from Washington to Mount Vernon will eventually be extended to the camp, a distance of 4 miles. The main channel of the Potomac runs close to the southern edge of the peninsula.

(*d*) Dogue Creek, on the east, and Accotink Bay and Gunston Cove on the west, furnish sheltered water suitable for boat and ponton drill,

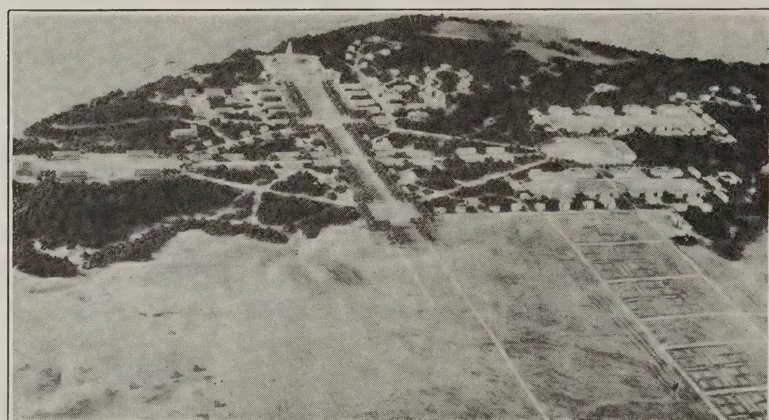


Fig. 2. Photograph of plaster model of proposed New Engineer Post and College of Military Research.

while the Potomac on the south affords opportunity for more difficult work by trained troops.

(*e*) Camp Humphreys has an excellent health record, a good water supply, and a climate that is seldom hot enough in summer or cold enough in winter to interfere seriously with outside work.

(*f*) The entire eastern coast and the country as far west as the Mississippi Valley are readily accessible at small cost and with slight loss of time, which will allow student officers to make many interesting and instructive visits of inspection covering the practical application of their theoretical instruction.

DESCRIPTION OF THE PROJECT.

The three groups of buildings that make up the project, viz, the Engineer School, the Engineer Post, and the College of Military Re-

search, have been arranged on the ground with a view to securing the maximum of efficiency for each unit with the minimum cost of upkeep, to securing the minimum cost of construction, and to taking full advantage of the natural beauty of the surroundings so as to produce a pleasing and artistic ensemble.

The style of architecture proposed is an adaptation of the best period of the Southern Colonial, and is characterized by brick walls with limestone trim, high roofs over two-story buildings, high chimneys, and one high feature, such as a tower or dome.

The location of the project is just to the south, and immediately adjoining the present camp. The accompanying illustration of the model represents the completed project. This model was cast in plaster and reproduces accurately the topography, foliage, and buildings on a scale of 100 feet to 1 inch. It corresponds to an airplane photograph taken from a point about 1 mile north of the center of the project.

The Engineer School is to occupy the southern end of the main axis, an extension of one of the main avenues of the present camp. The buildings in this group are to overlook the Potomac, from a height of about 150 feet, presenting an imposing appearance from the river as well as from the land approaches, being designed to serve the following purposes:

(1) The Engineer School of Application for officers commissioned in the Corps of Engineers;
(2) The Engineer School for Line Officers of the other combatant branches;
(3) The School for National Guard and Reserve Officers of Engineers;
(4) Correspondence School for National Guard and Reserve Officers of Engineers.

The school buildings have not been planned with a view to accommodating a definite number of students. The field facilities and the laboratories form the real foundation of the school, with a view to covering the engineering field in a thorough manner, without duplication of equipment; the idea being to arrange the various courses so as to obtain the maximum service by keeping the laboratory equipment in almost constant use.

The vocational schools are planned to occupy an integral part of the Engineer School, and should be sufficient for the training of one thousand men at the same time. The principal subjects to be taught in the school are:

Blacksmithing; Masonry;

Carpentry;
Drafting;
Surveying;
Electricity;
Gas engines;
Automobiles;
Lithography;
Steam engines;
Photography;
Plumbing;
Rigging;
Stenography;
Oxy-acetylene;
Machine-shop work;
Railroad operation;
Camouflage.

Courses in general education will include reading, writing, arithmetic, grammar, history, geography, and civil government. The various classes of enlisted men who will attend these schools have already been discussed. For the engineer post provision is to be made for two regimental units. The barracks are designed for 250 men each, with separate mess halls, headquarters buildings, guardhouses, exchange, garage, etc.

The College of Military Research is to occupy the eastern promontory, with quarters for the officers of the college in a separate staff village, situated about a mile to the north of the college.

There are to be several general buildings for the use of all units. These are the post administration building, chapel, officers' club, garage, and railroad depot.

UTILITIES.

Many of the utilities now existing at Camp Humphreys are of so permanent a character that there is no necessity for replacing them in the new project. The development of communications involves merely the extension of the present system of roads, railroads, and electric line, and the building of a new wharf on the river. The present railroad terminal with its warehouses needs no change, but a new station building will be required, near the northern end of the post.

A portion of the present base hospital will suffice for the new project. The laundry and refrigerating plants are more than ample. The pumping and filtration plants serving the present camp have a capacity of two and a half million gallons a day, which is sufficient for both camp and post. Electric power is now received from Alexandria, over a Government-built line; in view of the fact that a large boiler plant will be needed, for heating the buildings of the new project, it will be more economical to generate all the power needed and use the exhaust steam for heating purposes. Gas for cooking and water heating will have to be provided from a central plant. A portion of the present sewer system can be used, and the necessary extensions present no difficulties.

All the utilities for the project, comprising water supply, electric light and power, steam heating, ventilating, gas supply, interior plumbing, lights and gas, sewers and sewage disposal, have been carefully worked out in detail. They are modern in every respect and will ensure adequate service with minimum cost of maintenance.

Concrete Dry-Dock Construction for Portsmouth Navy Yard.

One of the largest dry docks ever constructed has just been completed at the Portsmouth, Va., Navy Yard. The dock is 1,000 feet long and required 185,000 cubic yards of concrete.

The foundation was excavated with 5-yard drag-line excavators and much time was saved by using this method, as the drag-line machines operated from the bank and therefore did not interfere with the construction of forms. The excavation went through an 18-foot fill of rubbish and beach sand, then 40 feet of heavy blue-clay; the bottom was in hard marl. Work was started on the river end, which was closed off by a clay embankment, down the center of which was driven a line of 45-foot steel sheet-piling. Total excavation 625,000 cubic yards.

The mixing plant consisted of two 2-yard mixers, with a third mixer held in reserve to insure the continuous operation of two mixers. These discharged into 2-yard side-gate car bodies, two of which were mounted on a standard flat car, eight flat cars being thus equipped.

The monthly average of concrete was 12,000 yards, the best record being for May, 1918, when 16,600 yards were placed. The best single day's run was made by one 2-yard mixer, which placed 1,150 yards of concrete in 22 consecutive hours on December 20-21, 1917.—Extract, *Engineering News-Record.*

Largest Use of Electric Power on Construction Work.

The largest use of electric power for construction work is in the Dayton, Ohio, Flood Protection Works, in which 8,000 horse-power is used. The power is obtained from a central plant and is distributed to the seven major construction operations by a three-wire high-tension line, the longest of which is 40 miles. Due to the length of line and the corresponding power losses, it was decided to step-up the current from 6,600 volts at the central station to 33,000 volts. At each operation, it is stepped-down to 2,300 volts for job distribution and again stepped-down to 440 and 220 volts for lighting and machine motors. The current is 3-phase, 60-cycle.

The power is used by motors from 5 to 500 horse-power, which operate pumps, concrete mixers, excavators, screens, compressors, shop tools, hoists, lighting, etc.—a total of about twenty operations—the larger motors being those of the drag-line excavators, which are from 200 to 280 horse-power. The largest motors are 500 horse-power and operate the 15-inch dredge pumps; they receive current at a pressure of 2,300 volts.—Extract, *Engineering News-Record.*

WATER SUPPLY FOR A FIELD ARMY.[1]

By

Mr. Arthur H. Pratt.

Engineer, North Jersey District Water Supply Commission (formerly Major, 26th Engineers, U. S. A.).

One of the many responsibilities of the Corps of Engineers is the water supply for troops in the field. The importance of this matter was recognized early in the war by the Chief of Engineers, and the 26th Engineers (Water Supply) was one of the first special service engineer regiments to be organized. The officers of this regiment were selected from civil and mechanical engineers who had had experience in civilian water supply work, and the enlisted personnel was recruited and inducted from the appropriate trades. This organization was mobilized at Camp Dix, New Jersey, and sent to France in several detachments, as their services were required. These troops were used at first on various water supply projects at base ports, hospitals, and other establishments in the intermediate section, and in the troop training areas in the rear.

A part of the front line was occupied by American troops in the winter of 1917-1918 as the beginning of a military program by which each division, as its training progressed, was actually to occupy trenches in a "quiet sector." That the term "quiet" has only a relative meaning will be realized when the reader recalls the fatalities in the 1st and 26th Divisions during the winter before last. When this program had progressed sufficiently an American army corps was organized, and under the corps engineer in June, 1918, the first water supply troops to take the field in the Zone of the Armies (Co. B, 26th Engineers), entered the Toul Sector to take over existing water facilities which, up to that time, had remained in charge of the French *Service des Eaux*.

ORGANIZATION.

The question of water supply is so closely connected with the topography and geology of a region, and it is so necessary for perma-

---

[1] Other articles treating of various phases of this subject have appeared in other engineering publications, in particular, *Engineering News-Record* (May 9, September 5, 1918).

nent personnel to be assigned to the operation of water utilities, that it is quite impossible for combatant engineer troops (sappers), who are frequently moving in and out of the territory, to handle satisfactorily the matter. This is one of the reasons why the special troops are provided, and for the same reason they operate under the direction of the highest and most permanent engineer command in the field—that is, the Chief Engineer of the Field Army—although in close liaison with the Corps and Division Engineers.

There is supposed to be a water supply regiment, of six 250-men companies, with each field army, which consists of about 500,000 men. The commander of this regiment is the assistant to the Chief Engineer of the Army, for water supply matters, and together with the necessary assisting staff officers constitute the Water Department of the Chief Engineer's Office. The army area is divided into two main districts, the field work of each being in charge of a battalion commander, and these again divided into three sectors with a water supply company in each. It is intended that the company commander will remain permanently in his sector, constructing and operating all needed water facilities. Water supply troops do not move in and out with combatant units, except as the tactical situation requires movement forward or back. This method of permanent assignment was used by the French with entire success, but, on account of the extraordinary emergency character of our operations, the theoretical organization of the water service was not adhered to any more than were a good many other theoretical matters.

There was but one water supply regiment in France, although we finally had three armies in the field. The organization of a second unit was in progress in France when hostilities were suspended. The 26th Engineers was therefore divided as conditions demanded, was "diluted" at times with other technical troops, and had various pioneer infantry and labor troops attached to it. During the period of most active operations, the First Army had four companies of water supply, four companies of pioneer infantry and a water tank train; in all, about 2,400 men engaged on water supply work. During the same period the Second Army had the other two companies of the 26th Engineers, two companies of pioneer infantry, one colored labor battalion, and a water tank train, totaling about 1,500 men.

THE WATER POINT.

Water is furnished to the soldier either from the individual canteen or the company Lyster sterilizing water bag. The latter contrivance, consisting of a 36-gallon waterproof canvas bag having faucets, was

devised by the Medical Department of the Army, and has been a most satisfactory article of regular troop equipment for some time. It is hung from any convenient place and permits the treatment of its contents with hypochlorite of lime, which is issued to the troops in convenient 1 gram capsules. The usual dose used by the medical officers is one capsule to the bag, which is equal to about 3 parts per million of chlorine, an amount which is very evident to the taste.

The Lyster bag, and the canteen as well, are generally supplied with water from the company water cart, which for foot troops is usually a 110-gallon, 2-wheeled, horse-drawn vehicle. The purpose of the water point, which is established by the special water supply troops, is to provide a place for the filling of these water carts.

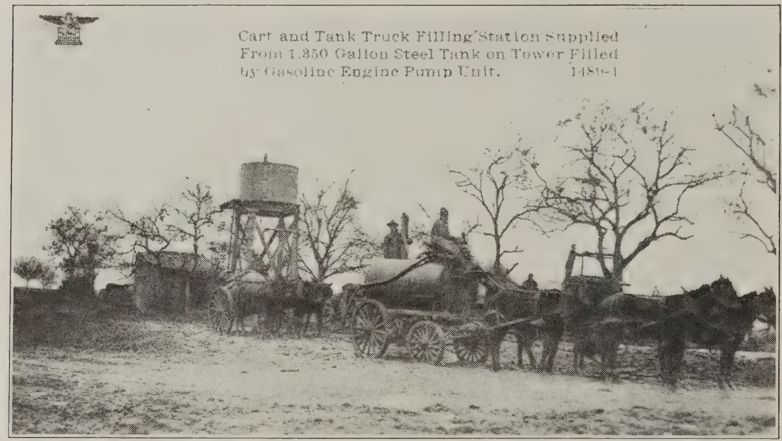


Fig. 1. Water Point at Essey; 3 filling standpipes; water from Essey filter plant.

Water for the water points is obtained from many sources, in the same manner as any civilian installation would be developed; in villages, where the civilian supply is available, in central fountains, at hydrants or wash-houses (as is the custom in France) additional fixtures may be installed and, if necessary, the source may be developed so as to increase the quantity. In villages which have been destroyed the civilian installation may still be available, after some repairs. The local supplies of many villages in the Chateau Thierry region were thus reinstalled by troops of the 26th Engineers and the French *Service des Eaux,* soon after their occupation by Allied troops. Local wells and springs may be improved, new springs searched out and developed,

and, if the geology is favorable, even drilled wells may be put down. Finally, water may be obtained from surface streams and ponds, but such a supply is likely to require settling basins and filters, and should be provided, in any case, with disinfection treatment.

The facilities required at a water point had been definitely determined, through bitter experience, by the British and French before the American Army reached the battle line. These consist primarily of a storage tank having a large enough outlet to fill water carts by gravity in a very few minutes. If the source is at sufficient elevation to accomplish this without pumping, so much the better; if not, power pumps must be installed. Steel tanks of about 1,200 gallons capacity, having 2-inch or 4-inch outlet gate-valves, were preferred by the Ameri-

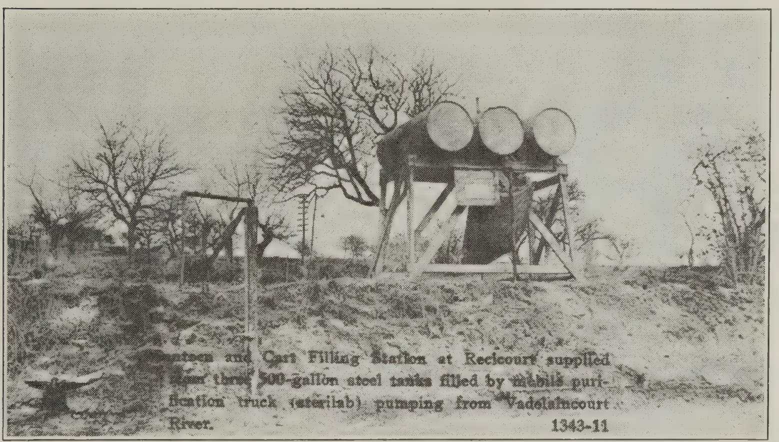


Fig. 2. "Argonne," showing use of battery of small tanks when a large one is not available.

can service for this purpose. When there was time and the topography was favorable, concrete or rubble masonry tanks were built. When large steel tanks were not available several small ones were used, or wooden casks, gasoline barrels; indeed, anything that would hold water. A successful tank taken over from the French which was boxed-in to prevent freezing was later on found to consist of two concrete dump-car bodies. The British developed very successfully a canvas tank which, when elevated, was supported by a wooden framework. The French water service, which was very short of steel tanks, built at one of their army parks a very satisfactory light reinforced concrete tank of 750 gallons capacity. This tank was a beautiful job of concrete. It

was only 1¼ inch thick and weighed but 2,400 pounds, empty. Several were hauled a considerable distance in a motor truck and installed with entire satisfaction by the American service. Besides facilities for filling the water cart, the water point may have provision for filling individual canteens, consisting of a string of Lyster bags or a line of small taps; larger faucets may be furnished for the filling of pails or other receptacles. It may also be convenient to establish a shower bath near by.

The water point is located as convenient to the troops as possible, but it is evident that water can not be piped to every company kitchen. A distance of 2 kilometers was believed, on the one hand, to be a practical haul for water carts; but, on the other hand, a long haul means increased road congestion. Such a provision would mean water points not farther apart than 2.5 miles. The water engineers endeavored to distribute these facilities judiciously, piping for some distance if necessary. The point should be near a good road, but not on it where it would stall traffic unnecessarily. Crossroads, being a favorable place for the enemy to shell, are avoided, as are also artillery positions. Conspicuous signs are placed directing traffic to the water point—"Water for Men and Animals, 700 meters." At the point, traffic is controlled, order maintained and sanitary regulations enforced by a water guard, a soldier of the water service wearing a white brassard with red "W. S." Water points on the light railroad for furnishing water for locomotives and for the railroad tank cars are provided in a similar manner.

The location of all these water points, and facilities provided, are indicated in detail on maps showing various army facilities, which are lithographed at the Office of the Army General Staff and distributed periodically down to and including the General and Technical Staffs of Divisions.

WATER QUALITY.

The responsibility for the sanitary condition of the water in the canteen and Lyster bag is placed by Army Regulations upon the Medical Department. The medical officer's responsibility ceases, however, at the water point, at which place the Army Water Service must either supply a potable water or, if not, the proper Medical Department officer must be formally notified so that he may treat the water either in the water cart or in the Lyster bag. The advantages of providing a potable supply at the water point are recognized by all, and where the source was of any considerable size and showed pollution, generally some form of treat-

ment was provided. Liquid chlorine apparatus was most satisfactorily used for this purpose in the American Army to the limit of availability of this special equipment.

Treatment at the water point permits more competent supervision, the chemicals added may be more exactly proportioned to the requirements, and the undesirable taste caused by the customary overdosing in the Lyster bag avoided, resulting in assurance of all personnel using only treated water. With the best intentions and most careful supervision chlorination in the Lyster bag is frequently neglected. The skilled personnel of the water service is generally able to deliver a sterile, tasteless water. The importance of this can not be overestimated, for the prejudice against the taste of chlorinated water is not confined to the enlisted personnel—many of our "educated" officers being equally indisposed to drink it or to compel others to do so, regulations notwithstanding.

The addition of Javel-water is standard practice in the French army, and where water points having this method of treatment, already installed, were taken over by the American service the practice was continued—the solution being purchased from French army laboratories. At a few places where large supplies were obtained from a turbid stream, complete settling basin, rapid sand-filter and chlorination plants were built, having a capacity as great as 150,000 g. p. d. These plants are worthy of a more complete description than can be given in this article, and will be presented at another time in more detail.

The detailed supervision of matters of water quality, analysis and treatment was in charge of officers commissioned in the Sanitary Corps of the Medical Department, especially selected on account of their expert experience with water analysis and water treatment in civil life. They were assigned to the water organization and operated under the direction of the various sector and army water supply officers, with such general technical supervision as was required from the Central Water Analysis Laboratory of the Water Supply Service at Paris. Facilities for water analysis were provided in the field by mobile laboratories, consisting of a housed-in body containing necessary laboratory equipment, all mounted on an automobile truck.

For use in advanced positions where there was not time to construct such a water point as has been described, the mobile water purification units were very successfully used. These consisted of a mechanical sand-filter, gasoline-engine-driven pump, chlorinating apparatus, small laboratory and suction and discharge hose, all mounted on an automobile truck. These units were built by Wallace & Tiernan Co., Inc.,

New York. Some improvements were made in the original design, and the later units had enlarged pump capacity and increased truck strength and power. Still further improvement of this equipment, based upon its extensive use with the armies, were well along towards being realized when hostilities ceased. These mobile purification units, with filter, proved such a success that they will become permanent items of the Army engineer equipment.

WATER FOR ANIMALS.

Facilities must also be provided for watering animals. The leading of horses into a stream for watering is very undesirable. Frequently the banks, do not give convenient access to the water and, unless the bottom is very hard, it soon develops into a very uncertain footing for the horses, resulting in loss of valuable animals; and there is the objection to the fouling of the stream, water from which is often used for drinking purposes at another point. Watering troughs should be provided, and also pumps, if a gravity supply is unavailable. Along the Marne River the French installed many horse-watering places, consisting of 100 feet of wooden trough, a gasoline-driven pump in a small house, together with a plank standing. The British use canvas tanks, resting on the ground, large enough to give a storage of 600 gallons, which is very useful for carrying over the peak load. Wooden, concrete and steel troughs were all used by our armies, and the canvas trough had also been adopted, but deliveries had only just begun when hostilities were suspended. The future standard equipment is likely to be a sheet-metal trough designed to be nested for shipment.

Horse-watering places are located at convenient points, but off the main roads, so as not to obstruct traffic. They are also separated from cart-filling points for the same reason—even if the water for both is drawn from the same source. A greater quantity of water is required for animals than for men, for a horse drinks five or six times as much water as a man, and there are a quarter as many animals as men in a division. The quality of course is not so important, although horses require a decently clear water.

A MOVING ARMY.

The progress of an army is not continuous, but consists of a series of advances and rests. During the latter the "consolidation" of the water supply is developed, the same as the multitude of other facilities, in anticipation of the extraordinary demands that will be made when

Fig. 3. Temporary advance reservoir lined with canvas.

Fig. 4. "Argonne"; Water being hauled on ammunition truck—probably in G. I. cans.

troops concentrate for the next offensive, when the roads are crowded for miles with trucks and guns, and when the woods are filled to overflowing with men and animals. The localities where troops will probably concentrate are usually known, and it is the duty of the water service to make adequate preparation for them. In some cases in the Toul Sector an extensive piped supply was built in woods for this purpose. One of these projects really amounted to a small town supply, and consisted of two 60 G. P. M. pumps working against 460-foot head, 30,000 feet of 2-inch and 4-inch pipe lines, storage reservoir, taps at convenient places, shower baths, and horse-watering troughs for the use of the thousands of troops and animals being concentrated at a point invisible to the enemy. Many similar installations were discovered on the German side of the line, after the taking of the St. Mihiel salient.

An important item to be considered at this time is the filling point for the army water tank train. As an army advances, the development of water points from a local supply becomes increasingly difficult. Resort must be had to the hauling of water in wholesale quantities. For this purpose certain water points, strategically located, and having abundant supply, are developed previous to an offensive, and these are specially equipped to fill large automobile water tanks. A train of these tanks is part of the organization of each field army, their operation being under the direction of the water supply service. These tank trucks are filled at the large water points and are pushed forward as far as the roads will permit of motor traffic. There, hastily constructed reservoirs, consisting simply of a hole in the ground with a canvas tarpaulin lining, are provided, into which the motor tanks are discharged. The company water carts draw from these reservoirs by means of a hand-pump, which has been previously installed. As the troops advance, these reservoirs are replaced, when possible, with regularly established gravity filling water points. The water tank trucks in the A. E. F. were of various types and capacities, but experience indicates that about 750 gallons, in three compartments, is the most desirable size for the rough roads that will be encountered in such operations. The preparation of the motor-tank filling points is one of the most important functions of the water supply service. It was for such a purpose that the larger filter plants, previously mentioned, were constructed along the Mad River, in the Toul Sector. The offensive for which they were to be used, however (the capture of Metz), did not materialize, on account of the cessation of hostilities. Water was also hauled in 2,000-gallon narrow-gauge railroad tank cars.

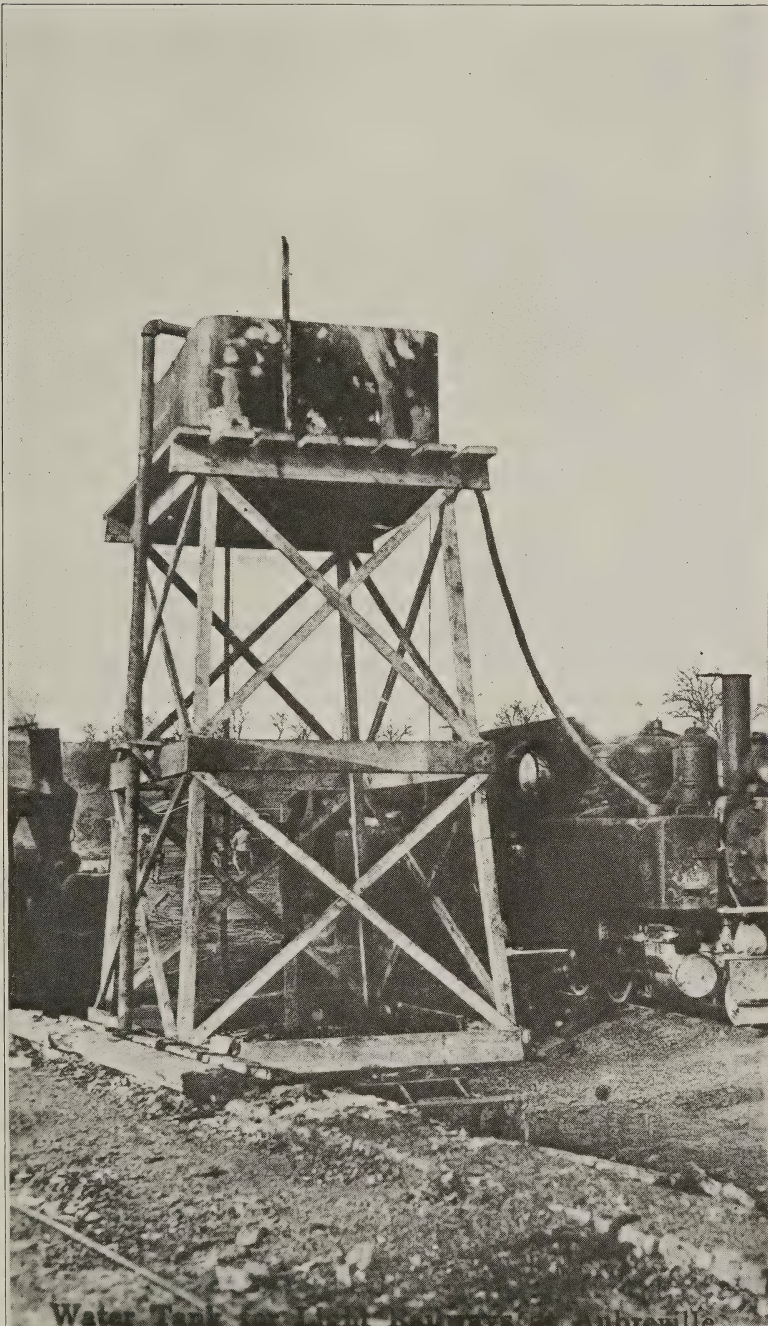


Fig. 5. Water tank for light railway at Aubreville.

Reliance is not placed on water hauling alone, but, in addition, small detachments of water supply troops follow the advancing infantry, to put into commission as quickly as possible any water facilities found in the enemy country. Each detachment is accompanied by a horse-drawn wagon, containing hand-pumps, pipe, well-cleaning apparatus, hypochlorite of lime for sterilizing wells and tanks, hose for emergency connections, canvas for lining reservoirs, etc. On account of road conditions, horse transportation permits these parties to advance much farther than would be possible if only motor transportation were available. As soon as motor trucks can be put on the road the mobile purification units are pushed ahead and installed.

In the St. Mihiel Sector and around Metz the Germans, on account of their possession of the French coal fields and their shortage of gasoline, used central electrical generating stations, high-tension power lines, and electric motors for their pumps. When these plants were captured they were again put into commission, as quickly as possible, by substituting an American gasoline engine for the German motor, which had generally been removed, and using the German pumps, which frequently had been only a little damaged. An interesting case is that of a French town pumping plant which was put out of commission by the French when they retired in 1914. The Germans installed electric motors, which they, in turn, removed when they retired in 1918; the American service installed a gasoline engine, the pumping plant still being in commission and having been operated practically continuously during the war by French, German, and American engines, successively.

EQUIPMENT.

The 26th Engineers were armed and equipped the same as infantry, for when engaged on construction work and pump operation in advanced positions the soldiers were subject to the same shell fire and gas attacks as any other troops. A water supply regiment is equipped with motor vehicles to move its technical equipment and troop property. Tools should be packed in standard sized boxes fitting economically into truck bodies. The motor truck-mounted machine shop, carpenter shop, and blacksmith shop, developed by the Engineer Department were successfully used, and in the future will be part of the regular equipment of water supply troops. Every effort is, of course, made to simplify the materials carried. Pipe sizes were standardized to 1, 2, and 4 inch diameters, and the number of specials reduced to a minimum. Gasoline-engine pumps were used exclusively by the American water service; they were of both French and American manufacture.

Steam fire-engine pumps have been used by the British, but the opportunity did not occur to try them out in the American army. The hand-pumps were mostly French. An interesting French hand-pump, especially adapted for depths greater than the usual suction lift, is the Chain Relice pump, consisting of an endless chain, surrounded by a wire helix, which passes through the water and over a wheel. This, when revolved, lifts a film of water which is diverted and discharged at the mouth of the pump.

Part of the region in front of Metz is flat and consists of a fissured limestone, overlaid with impervious clay. This not being a favorable formation for springs or wells, the French water service found it desirable to drill deep wells into the fissured limestone. It so happened that the French officer in charge of water supply work in that district had become familiar, in his mining practice, with the American Calyx drill, and used it very successfully for water supply purposes in that region. It is also a matter of interest that many of the gasoline engines driving deep well pumps were manufactured by the National Harvester Co., and handled through their agency in Paris. One of the peculiar fortunes of war was that after the Americans occupied this sector, and took over the maintenance of these pumps, it became impossible to get separate parts for this American machinery in France. Percussion well-drills are part of the American water service equipment, and were used to limited extent in this sector; they would have been used considerably more had the war lasted. A part of the enlisted personnel of the regiment had been specially recruited and inducted from the expert well-drillers of the Southwestern oil fields.

PERSONNEL.

The following officers of the Corps of Engineers were principally responsible for the water supply operations in the Zone of the Armies; Brig. Gen. Harry Taylor and Maj. Gen. William C. Langfitt, chief engineers of the A. E. F.; Col. F. F. Longley, officer in charge of the water supply section of the Chief Engineer's Office; Brig. Gen. Jay J. Morrow and Col. George R. Spalding, respectively, chief engineers of the 1st Army; Lieut. Col. F. W. Scheidenhelm, water supply officer, 1st Army, and Brig. Gen. Herbert Deakyne, chief engineer, 2nd Army, under whom the writer served as officer in charge of water department. Lieut. Col. E. Bartow, Sanitary Corps, was in charge of water supply laboratories.

FURNISHING TIMBER FOR MILITARY OPERATIONS.

By

Lieut. Col. W. B. Greeley,
Engineers, U. S. A.

The engineering demands of the war of 1917 are well illustrated by its enormous and varied uses of timber. Including material actually put on the ground into depot or project stocks, the American Expeditionary Force required 450,000,000 board-feet of round or manufactured timber to carry its operations to the end of the war, together with 650,000 cords of fuel wood; 38½ per cent of this vast consumption was in the form of construction and fortification lumber of small dimensions, bunk and duck-board material, etc., while standard-gauge ties were represented by 13½ per cent and large timbers for bridge, dock, and barge construction by 9 per cent. Six per cent of the army's requirements—the most difficult of any to supply—was for piling, while another 6 per cent covered the requisitions for telephone poles, camouflage pickets and entanglement stakes. In the consumption of forest products as a whole, fuel wood stands second, with 27 per cent of the total.

Probably 80 per cent of these quantities, with the exception of fuel wood, were used for supply facilities, installations, and depot stocks in the zone of the rear. Consumption for these purposes was, of course, abnormally high, because of the fact that the American army had largely to create its own supply facilities and its zone of the rear in a foreign country. A study of the orders received by the forestry section and of the authorized dump and depot stocks, however, indicates that an army of 500,000 men operating in the zone of combat under the conditions of warfare prevailing in France, requires around 18,000,000 board-feet of timber per month, exclusive of fuel wood. The principal items in this total are 4,500,000 feet of construction lumber for supply facilities, 4,135,000 feet of material for field fortifications (gallery frames, lagging, revetments, etc.), 2,000,000 feet of railroad ties (62,500 pieces), and 1,600,000 board-feet each for bridges and road plank.

The experience gained in furnishing these vast quantities of material under French conditions may be of value as indicating how like emergencies may be met in the future. Transport conditions forced the American army to be largely self-sustaining as to its timber requirements. Barely 1 per cent of the total quantities consumed was transported from the United States; and on account of the shortage of manufactured materials in France and difficulties in transporting articles of such bulk from neutral European countries, over 75 per cent of the timber required by the American army had to be cut by its own troops. The purchase of such supplies from commercial stocks or under contracts with commercial agencies is by all odds preferable from the standpoint of cost and of the quality of the materials obtained. However, two features of modern warfare bid fair to render it impossible to supply armies in the field with any considerable part of their timber requirements from the customary sources of peace-time supply. These are (1) the enormous quantities of timber used in field operations, particularly those of a stable character, and (2) the congestion of transportation. Lumber is bulky; and in comparison with munitions as a whole is apt to stand low in priority ratings, which control the use of inadequate transport facilities. If forests exist in the theater of operations, an army which anticipates a campaign on a large scale and of extended duration had best be prepared to cut its own timber as it goes.

The experience in France has demonstrated that to do this is a comparatively simple matter for engineer troops equipped with mobile machinery. Sapper regiments have always been equipped with woods tools and have cut stringers, poles or revetting material as occasion demanded. To equip the sapper regiments attached to divisions, corps or armies more effectively for work of this character when necessary, it is believed desirable to have available for them, not of necessity in the field but in depot stocks, enough light, portable saw-mills of the type, described later, which are both transported and operated by caterpillar tractors, to equip two companies in each regiment. With such equipment, sapper troops could at a pinch cut practically anything required, if standing timber is available, and meet the emergencies which are bound to occur in supplying material of the right kinds from the rear. It is obvious, however, that with the tremendous demands made upon sapper troops for all sorts of engineering work, such regiments can not be expected to cut timber except for emergency requirements. If the bulk of the timber needed can not be supplied

from commercial sources by the customary methods of purchase, it must be cut by specialized engineer troops.

The personnel for an organization of this character, well prepared to jump into the work immediately without preliminary training, can be obtained from the forest industries and from the state and federal forest organizations of the country. It is unnecessary to retain such troops in the peace-time establishment of the army or to train regular engineer regiments in these specialized duties. The experience of the American army in France indicates, furthermore, the desirability of the simplest and most flexible form of organization for troops of this nature, who are discharging primarily an industrial function. The forestry troops in France were combined under a single regimental headquarters (the 20th Engineers), which directed the work of 49 companies of technical troops and 36 companies of service troops, organized in 14 battalions and conducting a total of some 90 lumbering operations. The regimental staff was enlarged to permit an overhead organization corresponding to that of a lumber corporation, with officers in charge of the respective departments of timber purchases, technical equipment and operations, and the distribution and shipment of the product. The battalion organizations embraced geographical districts, which were made as stable as possible in order to gain the advantages of local familiarity with the timber and other operating conditions. Each battalion commander was a district commander, combining technical supervision and the military administration of troops in the same officer. The battalion staff represented the same operating departments as the headquarters staff and was given the widest possible latitude and authority in running the forestry operations of the district.

The experience of the American army in France also indicates the necessity of making a forestry organization of this character a distinct engineer service, directed as a whole by the chief engineer of the army or of its service of supply. When military operations are conducted on an extended scale and embrace many different activities under different branches of the service, there must be a central clearing-house for revising requisitions to fit the materials available, for cutting down excessive orders, for establishing the priorities of different requisitions, and for directing the current distribution of the forest products obtained in accordance with the transportation conditions of the moment and the relative emergencies of the different demands as they may change from week to week. Since the great bulk of the forest products are used for engineering purposes and by engineer personnel,

it is believed that this function is best discharged by the chief engineer of the army or its supply service, in accordance with the instructions of the general staff. Centralized control of forestry troops should not be affected by the geographical location of their operations.

An organization of this type does not necessitate delays or long-range approvals in meeting the requirements of local army units. As the territorial organization of forestry operations developed in France, it was a simple matter to put their local officers in direct touch with section engineers or with army and corps engineers, and to authorize them to accept and fill requisitions for timber locally needed without reference to regimental headquarters. The monthly credits authorized by the general staff for combat units also established automatic priorities which controlled the distribution of the cut of the nearest saw-mills. Centralized control exercised along flexible lines is believed to be the key to the most effective use of specialized engineer troops.

The effective location of forestry operations requires three things:

(1) A thorough reconnaissance of the standing timber in the theater of operations;

(2) Up-to-date information on the requirements of the army as to kinds of timber and points of use; and

(3) A careful study of transport facilities in relation to each proposed operation, including motor transportation. The largest and steadiest consumers of timber in France were the main base ports and depots, and next to them the large hospital projects. These demands formed a stable basis for 60 per cent of the forestry products. The requirements in the combat zone were much more difficult to provide for in advance, both as to classes of material and points of use. They were met by locating all of the saw-mills possible in the region directly behind the American sector and by putting the local district commander in touch with the army engineers, with full authority to move mills and troops to the most advantageous points.

While the concentration of forestry operations in the areas of best timber is preferable from the standpoint of volume and cost of production, transportation has the last word; and mills must be placed where their products can be moved most freely to the points of use. As a matter of fact, 80 per cent of the timber needed in military operations, covering their requirements for ordinary lumber, ties, fuel wood, stakes, etc., can be cut from any forests containing trees 12 inches and over in diameter; and for such products proximity to points of use should govern the location of forestry operations. For large structural

timbers and piling, on the other hand, the location of the best stumpage will usually determine where cutting must be done.

From these considerations it is evident that, taking our experience in France as a guide, the saw-mill equipment of forestry troops must be well balanced, with comparatively permanent types of plants adapted to operations near base ports and large depots in which rapidity of cutting a variety of products is the principal factor, and other types adapted to temporary operations in which mobility is of first importance. The experience in France also indicates that the equipment of forestry troops should include saw-mills at least 30 per cent in excess of the number of going operations anticipated at any time. This permits the constant setting up of new mills, as new locations become necessary, without stopping production at the existing plants.

The work of the forestry troops in France developed three distinct types of saw-mill operations which were well adapted to the varying requirements of the situation and have been taken as the basis for recommending future standardized equipment. The first of these was the saw-mill adapted to relatively permanent operations or roughly those where not less than 4,000,000 board-feet of saw-timber are to be cut at one set. This mill comprises a 50-horse-power locomotive boiler, with a 50-horse-power side-crank engine, which should be mounted on cement. It carries a 3-saw edger and two cut-offs, in addition to the circular head-saw. The mill and power weigh approximately 14 tons and can be set up so as to begin cutting in twelve days. Its ample power and the weight and substantial character of its parts permit continuous hard driving at high speed, which is the key to high production. Such a plant can be operated two shifts daily by a single forestry company with men to spare, and has a monthly capacity of from 1,000,000 to 1,200,000 board-feet. It can carry additional woodworking machinery if desirable; but it is heavy and slow to move and should not be reset oftener than once in four months.

The second type of saw-mill, carrying a 30-horsepower over mounted engine, can be set up in four days on timber foundations and will cut a variety of products equal to that of the heavier plant. The capacity of this mill, on account of its smaller power and lighter parts, is about half that of the heavier mill, but two plants can, under favorable conditions, be operated by a single forestry company so that the monthly production per troop unit with this equipment may not be materially less. The great advantages of this plant are its light weight

and comparative mobility. One of these mills in southern France was moved 35 kilometers, was reset, and began cutting its first log in 47 hours from sawing the last log at the old set. Another plant and crew were moved 100 kilometers and turned the same trick in less than 4 days. This light mill is adapted to the operation of tracts containing less than 4,000,000 board-feet of stumpage whenever an all-round cut, including a considerable proportion of square-sawn lumber, is desired.

The third mill is a little bolter machine, weighing 3 tons with all equipment, which can be operated by a 25-horsepower steam or gas engine of any type, but which was found to be most effective in combination with a 10-ton caterpillar tractor, both for operation and for its own transportation. This little plant can be taken down in 4 or 5 hours, loaded on a couple of log wagons, moved by its own power to a new site, and reset in a similar length of time. It carries a 48-inch circular saw and does its best work on logs 16 inches and under in diameter and 10 feet or less in length. It is an ideal little plant for slabbing ties or for sawing road plank or unedged boards, such as are used extensively in field fortifications. It is this type of mill which is recommended for the equipment of sapper regiments when the assignment of the unit involves a good deal of timber work. At a pinch, the little bolter mills can be made to cut almost anything. Their monthly capacity on two shifts a day is from 300 to 350 thousand feet board-measure; and a forestry company under average conditions can operate three plants of this character.

Aside from the various types of saw-mills, transportation equipment is of the greatest importance to forestry troops. The transport of logs from woods to saw-mill or of piling, poles, etc., from woods to railroad is, by and large, the most difficult part of forestry operations. The conditions in different localities as to topography, character of ground, size of timber, etc., vary so widely that the standard equipment of forestry troops must include several different types of transport to meet these contingencies. The equipment recommended includes spool skidders for short distance skidding, up to 200 yards, 4- and 8-wheel log wagons for longer hauls, heavy motor trucks with two types of trailers, a high-speed trailer with rubber tires and roller bearings for work on good roads and a slow-speed trailer with 6-inch iron tires for work in the woods, and 10-ton caterpillar tractors. The caterpillar was the last resort in hauling trailers or log wagons over sodden clay ground which was impassable to horses and to any other type of motor equipment. The 8-wheel log wagon was another life-

saver on soft ground, corduroy roads, or with heavy timber and other adverse logging conditions. It was also used successfully as a trailer behind trucks or caterpillar tractors.

This transport equipment, ample as it would seem, should be supplemented by 25-pound steel rail, with 10-ton gas or steam locomotives and light skeleton steel cars, built for a track of 3-foot gauge. The forestry operations in France were forced to resort to logging railroads or horse-drawn trams in many cases by lack of horses, lack of suitable motor equipment, the impenetrable clay mud of certain regions, the loose sand or swampy ground of other regions, and in some cases by the large quantities of timber to be moved over distances of from 1 to 4 miles. Aside from meeting emergencies where other equipment is not available or will not work properly on the type of ground, a railroad layout is, with favorable topography, usually the most satisfactory in operations comprising 6,000,000 feet of timber or more. In many small operations, tram lines operated by horses, which could be quickly laid and relaid, proved to be very effective. This was the case, for example, in the loose sandy soils of southern France, where traction by wagons was difficult. Sectional 40-cm. or 60-cm. track was found to be very useful for light products and in short operations, but lacks the stability necessary for sustained logging operations, particularly in heavy timber.

The rough-and-ready mechanical genius of the American lumberjack, trained in the American lumber woods, was one of the greatest assets of the forestry section of the Expeditionary Force and will prove so under any corresponding conditions in the future. An infinite variety of mechanical appliances were worked out to meet special conditions, such as "go-devils," or roughly constructed sleds, for short-distance skidding in mud or snow; heavy bob-sleds for distance hauling on snow in the French mountains; an incline hoist in the Vosges, down which carloads of logs were lowered by cable, and the like. Given substantial equipment of standard types and in ample quantity, the practical ability of personnel of this sort can be relied upon to make the necessary adaptations to each job. Every officer who has wrestled with the movement of bulky supplies in France will appreciate the particular need for ample transport equipment. This is especially vital in the case of forestry troops where, aside from losses due to wear and breakage, the units must be prepared in advance to move heavy products over different types of ground requiring different appliances.

One of the lessons brought home most sharply by the experience of supplying the Expeditionary Force with forest products was the necessity for specifications which are drawn to fit the timber rather than the technical design, which are simplified to the utmost degree, and which are standardized for all army services and departments. Simple, standard specifications avoid innumerable errors and delays in the handling of requisitions and shipments. In the absence of special orders, for example, the saw-mills in France cut their logs into the following material:

50 per cent 1 inch by 3 inches and wider, 4 feet and longer;
25 per cent 2 inches by 4 inches, 4 feet and longer;
15 per cent 2 inches by 6 inches, 4 feet and longer;
10 per cent 2 inches by 8 inches, 4 feet and longer.

Orders for millions of feet of lumber for construction projects were placed simply by wiring the total quantity and the percentages of 1-inch and 2-inch stock.

It must be borne in mind in this connection that military structures in the field are largely temporary and that standards of rough-and-ready construction, designed simply to accomplish the immediate purpose of the structure, as a rule are sufficient. When the pressure for quantity and for speed in production approaches that existing in France in the summer of 1918, specifications must be drafted so as to admit all sizes of lumber which can, within reasonable adjustments and expenditures of labor, be utilized for the purpose in hand, disregarding so-called defects which do not impair the actual utility of the timber. Such specifications increase the daily cut of a particular product, like standard-gauge ties or siding lumber, from the same mills, from 30 to 50 per cent. The designer of a building was apt to requisition his siding lumber as 1-inch by 12-inch or 1-inch by 6-inch boards 14 feet long. What he got, as a rule, was inch stock of all widths and lengths, which made it possible to fill the requisition in one-third the time which would otherwise have been required and to put all boards coming from the saw to immediate use. In France over 90 per cent of the railroad ties were used in yard, storage depot, and siding trackage, which was temporary in character and carried relatively light traffic. Instead of a standard 6-inch by 8-inch tie with a face of uniform width, we shipped to these projects many ties not up to full specifications and many ties with excessive wane, provided that they had a minimum face of 5 inches at each bearing point of the rail.

By the adoption of this standard, the production of ties for the forestry troops in France was easily doubled over what it would have been had strict specifications been enforced. Similarly, the capacity of the mills to produce large quantities of road plank under rush orders was increased 100 per cent when the original specifications calling for a uniform 5-inch by 9-inch stick, square sawn on all edges, were modified to admit plank in any width from 5 inches up with reasonable amounts of wane.

The exigencies of a shortage of material also developed many uses for rough forest products which could be produced most rapidly or obtained near the points of use. Round poles were frequently employed for the framing of buildings in the place of sawn caps and studding; poles, mill slabs and fascines served as dunnage and pile bottoms at depots or field dumps; and, copying the example of the British, some of the small timber was cut into split poles (sawn through the middle, furnishing one flat side) for lagging and other rough structures.

Jacking Up a Five-acre Train Shed.

The large train shed of the Delaware, Lackawanna & Western R. R., at Hoboken, N. J., had settled from 5 to 16 inches and has recently been jacked up to correct grade without interruption to passenger service, which averages 50,000 per day. This shed weighs 9,000 tons and covers about 5 acres, it was jacked up with hydraulic jacks simultaneously. The work required about forty men and was started about July 1st and completed August 12th, 1919.—Extract, *Engineering News-Record.*

Concrete Freight Car.

Concrete Freight Car. (*Machinery*, Vol. XXV, No. 12, p. 1114, August, 1919.)—The first plans for the manufacture of reinforced concrete freight cars dates from 1909, when a patent for such a car was granted. Recently, however, a car of the gondola type was built by a western concern and tested under service conditions. The tests of the car, both empty and loaded, demonstrated its practicability for rough service. In the test without a load, it withstood extremely rough handling and switching. Then the car was loaded with fifty-five tons (10 per cent overload) of sand and turned over to a switching crew for service handling, which it also withstood without injury. Some advantages claimed for the concrete car are that it will not need painting, will practically eliminate maintenance charges, and will last much longer than the wooden car. As it is unaffected by its cargo, it is better adapted for hauling slag and ashes than a steel car. Plans are said to be under way for the quantity manufacture of these cars. The first one was built with the coöperation of the United States Railroad Administration, which is an indication that extensive production may not be delayed very long.

NOTES ON A DIVISIONAL ENGINEER REGIMENT IN THE ARMY OF OCCUPATION, DECEMBER, 1918, TO MAY, 1919.

By

Col. D. D. Pullen,
Tank Corps
(Captain, Corps of Engineers),
Commanding 314th Engineers, 89th Division.

During the march forward, the only engineer work that was required was reconnaissance of roads. This was accomplished by reconnaissance men on motor-cycles, who made the reconnaissance from two to three days' march ahead of leading elements of the division. The roads and bridges leading into Germany were all in good condition, so that the engineers were required to do very little work on them.

Road and billeting maps were made from time to time by reconnaissance parties and these were reproduced by the lithographic section. In this connection one thing was forcibly brought out, and that is the lithograph section must be provided with truck transportation. The division engineer and the lithographic section were required to be at division headquarters, and division headquarters only moved every second or third day, so this meant that the moves were so long that animal-drawn transportation was useless.

Whenever possible in the occupied area, the boundaries of division areas were made to coincide with political boundaries. This facilitated dealings with all civil officials and greatly assisted in the road and billeting reconnaissance. As by going to the *kries* seat (county seat), one could obtain nearly all of the information required about roads, though in regard to billeting a physical inspection had to be made of most of the towns, as it was found that the German idea of billeting did not always agree with that required by the Americans.

The occupied area was unique in that for four years very little maintenance work and no new construction had been done on any of the roads or public utilities. As a result the Americans found the roads without an ounce of road material available and all of the electric light and water plants were on the verge of breakdown. The American

engineers were immediately faced with two very serious problems: first, the repair and maintenance of a neglected road system; and second, the operation of the public utilities, which consisted of worn-out electric light and water plants.

The very first thing that happened whenever Americans occupied a town was that the load on the lighting and water systems was increased. In every case the electric light plant either gave trouble or failed entirely. The water supply only failed in a few cases.

It was only by prompt and vigorous measures that all of the electric plants and many water works were saved from being completely ruined. The first action taken was to place an officer in charge of all public utilities and to place an enlisted man in each town that had an electric plant or a pumping station. At first the main function of the enlisted man was to prevent the local Americans from making impossible demands upon the Germans in charge of public utilities. An order was issued which placed all public utilities under the engineers and prohibited the local commanders from giving any orders to the Germans in charge of public utilities or changing any of the public utilities in any manner without the authority of the division engineer. This simplified matters, as no changes were then made until after the electric light and water plants had been thoroughly investigated. All spare parts for the power plants had to be obtained from outside of the American area. This caused a great deal of difficulty and delay, as the Germans were not any too eager to expedite shipments when they were confronted with all of the regulations imposed by the allied military authorities. However, after things were once established, all plants were kept running.

The coal supply for the American area was controlled entirely by the French and, due to shortage and other difficulties, some of the power plants had to be shut down temporarily.

In the majority of the towns the water supply was free from contamination, though in some of the larger towns it was necessary to chlorinate the water. This was done with Lyster bags until improvised chlorating plants could be installed at the source of supply. Powdered chloride of lime was used in these plants until a supply of liquid chlorine was obtained.

All of the roads in Rhineland are water-bound macadam made from limestone, red quartzite or black trap. The German roads were quite a surprise to the American forces, as they had rather grown used to the French roads, which were wide and heavily metalled. In contrast, the German roads were narrow and thinly metalled and, as a result, all

of the German roads soon became impassable when subjected to the heavy American traffic.

The outstanding characteristic of roads in the Rhineland is that they consist of a narrow one-way metalled strip down the center of the road-bed. The shoulders of the road are kept flush with the metalled surface. American trucks in passing other traffic soon cut deep ruts in the earth shoulders; water collected in these ruts and softened up the edges of the metalled surface, and as a result the edges of the metalled surface soon gave way.

In nearly all cases the longitudinal drains were stopped up so that the subgrade was thoroughly water-soaked, and as soon as the thin metalled surface gave away all vehicles sank in up to their hubs.

The roads froze up in January and stayed frozen until March, so that during this period the problem of keeping the roads passable was very simple. Advantage was taken of this time to secure all of the road material possible and distribute it along the roads. This material came from two sources, small local quarries worked by hand and larger quarries outside the area operated by power. Most of the road metal obtained locally was limestone, which varied from very hard to soft. On the whole, this material gave fairly satisfactory results. Some red quartzite was obtained locally; this was harder than the limestone, and gave a better wearing surface. The material from outside sources was shipped in by rail and consisted mostly of black trap or red quartzite. The black trap was by far the best road material that was used overseas. The wearing qualities of black trap in Rhineland were so superior to that of the other road materials used that the contrast was very marked. Those sections of road made out of black trap called for very little attention, while the other sections of road made out of limestone or red quartzite required constant maintenance.

During March, the period of thaw, a great deal of difficulty was encountered, as the freezing and thawing of the water-bound macadam loosened up the road surface and road-bed to such an extent that heavy trucks would cut through the metalling. During this period of thaw motor traffic was suspended as far as possible, and animal transportation was used. In spite of this, the necessary motor transportation cut up some sections of the road so badly that it had to be entirely rebuilt. Due to the difficulties of getting sufficient road material and distributing the same, it was about the 1st of May before all of the roads were put in first-class condition.

Engineer soldiers and other line troops were used as road laborers during a short time only (about two weeks), covering the critical thaw

period. During the entire remaining time the Germans furnished all road labor, which was supervised by engineer soldiers. German laborers were paid the standard German wage; thas is, 6 to 8 marks per day, which at that time in American money was from 60 to 80 cents per day.

Upon investigation, it was found that for four years no work had been done on the road-drainage system. Consequently, the spring rains gave more trouble than would have been the case under normal conditions. After all drains had been opened up and cleaned out very little difficulty was had from the softening of the subgrade.

ROAD SIGNS.

The American Expeditionary Force had grown so used to an abundance of military guiding signs along roads and in towns that it was quite annoying to suddenly find one's self in a strange country with inaccurate maps and road signs few and far between.

As soon as the division was settled, sign-painting squads were organized and put to work. The sign-painters were organized into two sections—one of which worked in the shops at headquarters and the other worked on the roads. The shop section filled all orders from the road section. The road section was organized into squads; each squad was given a pneumatic-tired truck and assigned to a certain territory; by this method the work was carried out progressively and systematically.

The road sections placed orders with the shop section, erected all new signs, repaired those signs already in place, and printed new signs upon buildings or permanent structures in the field.

As far as possible signs were painted upon buildings. This saved material and made the signs more permanent. No doubt, for many years to come tourists in Rhineland will see the road signs of the American Army of Occupation.

After having experience with signs of all colors, shapes and sizes in France, the following general rules governing the construction and placing of road signs were followed:

1. All signs to be in black on white background.
2. White background to be outlined in black.
3. Letters to be from 3 to 12 inches in height, depending upon the importance and location of the sign. (In case of doubt use the larger letters.) In special cases, letters larger than 12 inches may be used.
4. All letters to be plain single-stroke, of the Rhinehart type.
5. All direction arrows to be made without the tail feathers.
6. On the first building located on every road leading into a town

the name of the town to be printed in large bold letters, of gothic block type.

7. All direction signs in towns to have the name of the local town at the top and the adjacent towns below with direction arrows. The name of the next small town to be given when more than one route to the large town existed. For instance—in the town of Bitburg, at the cross-road leading to Wittlich by the way of Erdorf, the sign shown in Fig. 1 would be placed.

FIG. 1.

FIG. 2.

8. All letters to be sloped in the direction of the arrow—for example, a direction sign in the town of Trier was like that shown in Fig. 2.

9. In addition, all through-traffic roads to be posted with simple direction signs, as giving only the name of the final destination, as shown, for example, in Fig. 3.

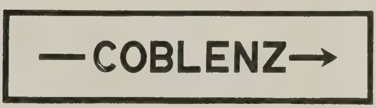


FIG. 3.

FIG. 4.

10. All signs to be marked by the organization which made them. (Fig. 4.)

11. On houses located at the corner of cross-roads signs of the

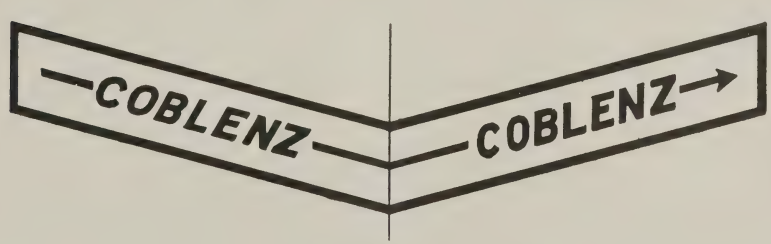


FIG. 5.

"around-the-corner" type to be used, similar to that shown by Fig. 5. This enables traffic to proceed at night without slowing up.

12. Wherever possible signs to be placed so that they will be illuminated by automobile headlights.

13. At cross-roads enough signs to be placed so that they will be visible from all directions of approach.

14. No superfluous words to be placed on direction signs, like "This way to ——." Names and direction arrows are sufficient.

RECONNAISSANCE FOR ENGINEER MATERIAL.

Except in the large towns, like Trier and Coblenz, the area assigned to the American Army of Occupation had never been occupied by troops; consequently, the small villages were not prepared to receive troops. It was easy enough to find billeting space for officers and men, but to locate proper kitchens, mess halls, stables and storehouses was quite impossible, as they did not exist.

Building material in France was very scarce and the railroads were being used to capacity to ship troops and equipment, so there was little hope of obtaining anything from outside sources. A thorough reconnaissance for all engineer material was made and it was found that the country was full of small saw-mills, the capacity of each one being from 1,000 to 2,000 feet per day. All of these mills were put to work and contracts were made with all local dealers for all of the building material that they could supply. In a very short time all of the building material that could be used was available.

All buildings were made of rough lumber and covered with tar paper. This type of building was easily erected and proved very satisfactory. The 314th Engineers carried on construction in 52 towns and the work comprised, among other items, such facilities as delousers, bath-houses, kitchens, mess halls, latrines, stables, storehouses, guard shelter along the border and railroads, recreation halls, dipping vats for horses, and shelter for the field bakeries.

Over one and a half million feet of lumber was used in the above construction. After the work was well started, an engineer dump was established at the rail-head. This dump was made up of building material of all kinds and engineer technical supplies for the division.

2,000 One-story Houses to be Built.

Two thousand one-story, three-room houses are to be built in France by an American contractor. They require ten million feet of lumber, which will be shipped from Jacksonville, Fla. The erection will probably be by French labor under American supervision.—Extract, *Engineering News-Record.*

FUTURE ORGANIZATION.

By

Lieut. Col. S. F. Crecelius,
Engineers,
Late of the 101st Engineers, National Army.

The timely article on "Future Organization" in No. 59, PROFESSIONAL MEMOIRS (September-October, 1919), should receive careful consideration and be discussed by engineer officers who served with the American Expeditionary Forces, in order that the lessons learned in the big school of experience may be applied in the reorganization of the engineers.

Each arm of the military service is in reality a big complicated business. It is a well-recognized fact that any business, to function properly, must be subject to a single will.

A capitalist, with varying business interests, would have a superintendent at the head of each separate and distinct branch of his business. If he had a number of units composing one branch of his business he would have a general superintendent to whom all of the superintendents of units would report. This general superintendent would coördinate the work of all superintendents and eliminate all possible duplication of effort, economize in the distribution and utilization of his personnel by transfers in order to attain the highest efficiency.

There are numerous classes of engineering work to be handled by the Army, all requiring the services of men who have had technical training. A great part of this training is common to the education of all engineers, regardless of the specialty of each individual.

Each separate class of work should have its head or superintendent, but the work of all should be coördinated by a general superintendent whose education and training qualify him to judge of the results attained by each.

Each class of army engineering work should constitute a service.

---

[1] The following comment on organization and duties of engineer troops in war was elicited by the article on "Future Organization" in the preceding number of PROFESSIONAL MEMOIRS.

The head of each service should report directly to and be responsible to the Chief of Engineers.

The organization within each service would depend very largely on conditions, but each engineer officer should be required to have a general knowledge of all of the engineering services and to be proficient in at least two, thus making a large number of trained men available for any unexpected expansion of any service and there would not be the waste of highly trained personnel that would result from independent services, all officered by engineers.

Any plan of reorganization to be at its best in time of war must contemplate the temporary utilization of civilians in appropriate grades in the various services for which they are qualified. These men should be organized into a reserve and given sufficient military training to impress upon them the necessity for the coördination of the work of all services.

The proper organization and functions of a sapper regiment have been subjects of much discussion ever since the American Expeditionary Forces took over a sector in France.

All engineer officers who served at the front seem to agree that the sapper regiment was too small to accomplish all that was expected of it. All agree that the personnel of the engineer train was too small and all agree that the engineer train should at all times be under the direct command of the Division Engineer.

The personnel of the headquarters detachment was too small, but with a band authorized as a part of the headquarters detachment it is possible that this difficulty is partially, if not wholly, overcome.

The rank of the Division Engineer should be that of colonel, for the following reasons:

1. The organization of the sapper regiment is more complicated than that of a regiment of any other arm of the service.
2. The operations of the sapper regiment cover a much larger area than that covered by a regiment of any other arm.
3. The varied activities of the sapper regiment require the supervision by a man of broader knowledge and more executive ability than is required of the commanding officer of a regiment of any other arm.
4. The Division Engineer frequently directs the work of two or more regiments of infantry, in addition to his own regiment.

It is important that the Division Engineer should command the sapper regiment, for in no other way can he understand the limitations of the regiment and have that intimate knowledge of the qualifications of his officers which he must have to handle the work with that quick decision necessary in many instances.

UTILIZATION OF THE SAPPER REGIMENT.

In all military operations provision must be made for two classes of warfare. Where the contending forces are of approximately equal strength, periods of stabilization are bound to occur. During periods of stable warfare, the duties of a sapper regiment are very different from its duties in war of movement.

Stable Warfare.

During periods of stable warfare the personnel of the sapper regiment may be properly used as follows:

1. For supervision of new work done and repairs made by the infantry in the first position, and to do work of a technical nature in this position that can not be done by the infantry.

2. To construct all works in the second position that must necessarily be completed in advance of the occupation of the position, such as obstacles, machine-gun emplacements, observation posts, dugouts for dressing stations and P. C.'s and (lines of communication) not handled by special units.

3. For tracing all necessary parallels and communication trenches on the ground in supervision of the work of reserve infantry in digging these trenches to the first stage.

4. For demolition work, including that done by raiding parties, which should always be under the supervision of engineers detailed to accompany the infantry.

5. An engineer officer should be detailed as liaison officer with each regiment of artillery and with each regiment of infantry in the line (the officers with infantry regiments remaining in the regimental sectors when reliefs are made). These officers should study the requirements of their sectors and each request of a line organization to the Division Engineer, for work or material should be accompanied by an indorsement of the liaison officer. (It frequently happens that one artillery or infantry regiment asks for all of the material of a kind in the division dump and for more work than could be accomplished by the whole sapper regiment in the given time.)

A good liaison officer, familiar with conditions on the ground and with the amounts of the various kinds of materials available, would suggest alterations and substitutions in plans securing the best results possible with the available materials and he would do much to eliminate friction arising from unreasonable requests.

6. The sapper regiment should be assigned a position in reserve or each battalion might be assigned a position in support, or one battalion might be placed in the support and one in reserve, but the sappers should never be called on to do duty in the firing line unless actually caught in that line at work, under which condition they should fight under the nearest infantry commander. (In the late war, sappers frequently stood at the alert all night and were expected to carry on their extension work without interruption.)

War of Movement.

1. Experience indicates that during an advance against determined opposition, the sappers will be thoroughly occupied with road construction and repair work, removal of obstacles and sanitary work. When advancing in battle formation each brigade of infantry should be accompanied by a company of sappers equipped with materials for the construction of at least 800 feet of light foot-bridge for the use of infantry. This equipment should be a part of the engineer train, and could be placed with the various companies when needed.

2. Liaison officers should keep in close touch with the needs of the advancing infantry and maintain communication with the Division Engineer.

3. The sapper regiment should be kept well advanced, in order that it may be available to assist in the organization of captured ground or that occupied when the advance is checked.

Notes.

Burnt Clay in Concrete Ships. (United States Geological Survey Press Bulletin No. 417, July, 1919.)—Burnt clay was used in 1918 for the first time as an aggregate for concrete in building ships. The war made it imperative that steel be conserved as much as possible, and the experiment of building seagoing ships of concrete was undertaken. It became necessary to make the concrete as light in weight as possible, so various light materials, including pumice, were tried. An aggregate made of burnt shale or clay proved to be a very acceptable substitute for stone and gravel in concrete, and its use reduced the weight per cubic foot from about 150 pounds to 118 pounds or, in some mixtures, even to 100 pounds. This aggregate was made near Birmingham, Ala., at Hannibal, Mo., and at Los Angeles, Calif. Its manufacture was not begun until late in the year, but enough was made to construct a 3,000-ton concrete ship, the *Atlantis*, which was launched in December at Brunswick, Ga.

Durability of Untreated Piling Above Low Tide. (Technical Notes, Forest Products Laboratory, Madison, Wisconsin.)—In tidal waters the portions of piles above mean low tide, although completely immersed only part of the time, may be practically saturated all the time. Wood constantly saturated with water is not subject to decay, and this fact makes the height to which saturation extends above low tide a question of considerable interest to the designing engineer.

The opinion of a number of engineers and construction companies, expressed in response to inquiries by the Forest Products Laboratory at Madison, Wis., is that untreated piling in water not infested with marine wood-borers will remain sound indefinitely if cut off at half-tide. This height ranges in various ports from 2.3 to 4.5 feet above low water. At certain places on the Atlantic Coast, piles cut off at the height of half-tide are still sound after from fifty to one hundred years of service.

Untreated piling is destroyed by marine borers more rapidly than by decay, and the information given would, of course, have no practical use where these organisms are active.

PERSONAL NOTES.

Harry Hodgman, for the past six years connected with Missouri River improvements as United States Assistant Engineer, with offices at Jefferson City, Mo., has been transferred to the Detroit River District. He will have charge, under the direction of Col. E. M. Markham, Corps of Engineers, U. S. A., of the widening of the Livingstone Channel.

Lieut. Waldo H. Chase, recently with the 115th Engineers, has resumed his position as engineer with the northern division of the State Highway Department, Cal.

Capt. O. E. Brownell, Engineers, U. S. A., has become associated with Morell & Nicholas, landscape architects and engineers, Minneapolis, Minn.

Capt. E. D. Hendricks, Engineers, formerly with 303rd Engineers, has been appointed division engineer of the eastern division, New York State, with headquarters in Albany. Work on all canals and terminals east of Utica and including New York City will be under Captain Hendricks' supervision.

Capt. John L. Bacon, U. S. A., formerly with 602nd Engineers, has received his discharge and has returned to San Diego, Cal.

Col. Earl I. Brown, Corps of Engineers, U. S. A., has been assigned to Cincinnati Engineering District No. 1, and will be in charge of improvements along the Ohio River in this district.

Capt. William E. Stanley, Engineers, U. S. A., has accepted a position with Pearce & Greeley, consulting, sanitary, and hydraulic engineers, Chicago. Captain Stanley will be resident engineer on the construction of a sewer system for South Charleston, W. Va.

Lieut. Col. Frank B. Maltby, Engineers, U. S. A., has received his discharge and will be a member of the advisory committee to the War Claims Board, Washington, D. C.

Capt. Harold M. Lewis, commanding Co. D, 502nd Engineers, has resumed his connection with Chas. W. Leavitt, landscape engineer, New York City.

Major Fred Patstone, 217th Engineers, has resumed his position as city engineer of Manila, P. I.

Capt. George B. McClary, Engineers, U. S. A., recently discharged, has joined Mr. Gilbert K. Cooper, of Chicago, and formed the partnership of Cooper & McClary, civil engineers.

Capt. W. E. Darrow, 33rd Engineers, recently discharged, has returned to his position as assistant engineer, New York State Highway Department.

Capt. Germain P. Graham, 20th Engineers, recently discharged, has resumed his work as assistant engineer in charge of construction, Bureau of Engineering, Albany, N. Y.

Capt. A. Stearns Wilson, Engineers, U. S. A., recently discharged, has reopened consulting and contracting offices at 51 East 42nd Street, New York, N. Y.

Maj. George Sykes, Engineers, U. S. A., died August 31st at Flushing, N. Y., aged 38. Before entering the army, Major Sykes was engaged in engineering and building construction in New York City.

Capt. Charles E. Ellicott, Jr., 105th Engineers, and Capt. John B. Norris, Jr., 51st Engineers, have both been discharged after over two years' service in France and will be connected with the Ellicott Machine Corporation, builders of hydraulic presses, Baltimore, Md.

Lieut. Col. Henry S. Spackman, Engineers, U. S. A., has received his discharge and resumed his work as president of the Henry S. Spackman Co., engineers, chemists, and inspectors, Philadelphia, Pa.

Capt. Jack J. Hinman, Jr., recently discharged, has returned to his work as water bacteriologist and chemist for the Iowa State Board of Health.

Lieut. Jack T. Nash, Engineers, U. S. A., has received his discharge and resumed his connection with the Henry Exall Elrod Co., Dallas, Tex., as Chief Engineer.

Lieut. Frank Mitchell, Engineers, U. S. A., recently discharged, has been appointed highway engineer of Thomas County, Georgia.

Capt. W. S. Wyche, 2nd Engineers, recently discharged, has rejoined the Arkansas Valley Railway, Light and Power Co., Victor, Colo. Captain Wyche was decorated with the Croix de Guerre, with palm.

Maj. A. H. Pratt, 26th Engineers, recently discharged, has been appointed designing engineer for the North Jersey District Water-Supply Commission, which is developing the Wauaque River at Midvale, N. J., to supply Newark and neighboring municipalities.

Maj. E. A. Kingsley, Engineers, U. S. A., recently discharged, has resumed his engineering practice at San Antonio, Tex.

EDITORIAL.

The Army Team—Get Together.

Every year the boys from one end of the country to the other, prep-school boys, high-school boys, college boys, get together and furnish their elders with an illuminating example in good citizenship and concerted effort for the common good.

They turn out by hundreds for the serious business of football—which, by the way, is a wonderful game, typifying vividly many things which all of us, statesmen, professional men, army men, business men, and average citizens, might study with profit to the country and to ourselves. In each school they turn out voluntarily in bunches to work for places on the team. Under the sweater of each is a budding ambition, the hope of making this or that place on the Varsity team.

For weeks they undergo the grueling monotony of training, gladly, eagerly, doing their level best to make good. Finally things begin to take shape and, from the bunch of aspirants, a team emerges. For every successful contestant, there are half a dozen disappointed youngsters who must content themselves with the comparative background of the scrubs, or who, perhaps, have to retire from the game. Some way they manage to down their disappointment in their hopes for the team. They know that there can be only one center, one quarter, one captain, two halves, two ends, and so on, and that's all there is to it.

When the team gets down to business, everybody turns to and roots for it. The team has a mission—it must uphold the honor of the school. Nothing but perfect teamwork, in the Varsity, in the scrubs, and on the bleachers, can make a winning team. The season begins. There are plenty of hard knocks, plenty of disappointments, individual and collective. Players pull boneheads and lose their places. The management sags and has to be bolstered up. Old fellows are called back and do what they can to patch up weak spots, and in one way or another the team pulls through the season. Comes the period of reckoning when everybody—management, teams, rooters, all sit down to figure out some good reason for being proud of the team's showing, some good excuse for each failure. As a rule, when they talk over the season's

work, they dwell on their successes—not their failures. They invariably end each discussion with a resolve to do better next season.

. . . .

Some years ago the Army slipped quietly over into the field of sport and appropriated from the youngsters a word, a fine, virile word, and incorporated it in the military vocabulary. That word was *teamwork*. In the operation they overlooked one thing—in their haste to appropriate the word, they failed to take the spirit along with it. They have cherished that word in the Army, have juggled with it, have had great hopes from it, but all to little purpose, because the spirit of the word is the whole essense.

What is that spirit?

Briefly, it is getting together, spiritually as well as physically, getting down to heart-breaking, shoulder-to-shoulder, self-sacrificing effort for the common good—effort in which the individual is glad to lose his identity in the team of which he forms a part.

. . . .

We had a war. We were not ready for it. Who was to blame for that is beside the question. We were up against it. We had to get down to business, throw together some sort of a fighting force and do the best we could. In throwing together this force everybody who could do so took a hand. Some of those who took part in the operation knew quite a little about the job; some knew a little; some knew nothing whatever, but were willing to learn.

The result? We got together an army of sorts, a team which required a lot of careful nursing, a lot of pushing and pulling and hauling, but which in the end accomplished our purpose—not economically nor in workmanlike fashion, but substantially. We may as well admit that we muddled, but we muddled through, which was as much as any one had a right to hope for.

The Regular Army, the National Guard, and a good part of the country at large, had a hand in the job. What part each played is neither here nor there. Each undoubtedly did his best according to his lights. A great many of each made good, did wonders considering the circumstances. Some of each were rank failures—which was not surprising, since we humans fail in everything about as often as we succeed, and, after all, war is only one kind of business. Statistics would probably show that the percentage of failure throughout was about even.

Now, in reviewing the season's work, do we thank our lucky stars that we got off as easily as we did? Do we congratulate the country

and ourselves that we did no worse in the face of our handicaps? Do we decide to let bygones be bygones and resolve to profit in future by our obvious mistakes?

It does not appear that we do.

Congratulations are drowned in the sound of knocking, knocking from all sides, among the members of the team, from among the old-timers and the newcomers alike, from the bleachers and from the by-standers. Instead of getting together and trying to hearten up things a little with a view to doing better in the future, the team is splitting up into bunches and passing the blame. And the rooters and the by-standers—without knowing much about the game except the spectacular part, they are finding fault with this or that player, criticizing the running of the team in general, pointing out where mistakes were made, and how, and by whom and how it should have been done, and so on down through the whole gamut of hostile criticism.

And nobody appears to be giving a thought to next season.

Of course, the fault lies with the players. They bungled because they had never had a chance at team-play. They had no chance at team-play because we had no team. We had no team because no one took any particular interest in getting up one. And that's the crux of the matter.

We are all grown-up men. Let's get together and play the game the way the boys do—but don't let them know it and have the laugh on us.

"All together—Let's go!"

An effort was made to fight the great war from which we are now emerging with the service divided into three forces—the Regular Army, the National Guard, and the National Army. In this national crisis it became necessary to combine these more or less antagonistic forces into one United Army of the United States, in which all worked for the success of the whole. If these forces drift apart, if advantage is not taken of the cohesive spirit that has been developed in the services generally, it will be increasingly difficult as time goes on to develop a really national force in periods of emergency.

By their close association on the battle fronts of France, the different arms of the Regular Army have been drawn together in mutual understanding and respect to a degree that had not existed before the war. It is hardly too harsh to say that the traditional attitude between the arms of the service in the old Regular Army was one of thinly veiled suspicion, jealousy and antagonism.

This present foundation for better understanding which the war has left as an incidental legacy puts the Army on the threshold of two choices, either we may revert to pre-war disjunction or we may sustain and strengthen the cohesion developed during the war. Inertia and a negative attitude will allow the service to drift back into the old conditions. On the other hand, a positive decision is necessary if solidarity is to be maintained and increased.

There are several reasons why an imperative necessity exists for cohesion throughout the services. The most important only will be enumerated:

First. There has been much misunderstanding and criticism arising not only from the mistakes of the Regular Army, but as well from the mistakes of the National Guard, the hastily raised levies, the emergency enactments of Congress and the historic lack of military policy and provision on the part of successive administrations and the American people. Therefore, a united front should be presented by all arms of the services to repel unjust criticism that may be leveled at any particular branch. At the same time, this solidarity should hold an equal willingness for each arm and the services at large to accept and profit by just criticism.

Second. There is in certain quarters a disposition to saddle upon the country a military policy which would perpetuate and increase the evils of our past history in political interference and divided control. This propaganda can not make headway with many of the thinking people of the country, provided the services themselves do not destroy confidence by friction and disagreement of ideas within their own ranks.

Again, without unity of purpose and harmony of doctrine no arm of the service and no one of the forces composing the Army can achieve its full measure of efficiency and usefulness. Mutual confidence is as necessary to success in the efforts of the different arms as in the relations of a family or in the transactions of business and banking.

If we agree that we ought to get together, the question then is, How are we going to do it? First of all, the services must realize that a radical overturn of thought and attitude is a human possibility, frequently exemplified. This nation was founded on the conceptions of individualism, which in the eighteenth century were cropping up independently in several quarters of Europe, and which dominated the political and economic practices of the unfolding modern world up to a period later than the middle of the ninteenth century. Now on every

hand we are confronted with the growing ascendency of collectivism over individualism. A man's house is no longer his castle. Our forefathers would have resented as a tyrannical intrusion upon their liberties the building restrictions, sanitary inspections, and ban on back-yard pigs and chickens which we accede to nowadays. The fathers of our democracy would have been horrified at the invasion of private property rights involved in the inheritance taxes to which we yield. It took an amendment to the Constitution to render possible the levying of an income tax.

So, in a modern world of overturn and inevitable radicalism, it is, after all, a simple change in viewpoint for the Army to cast aside its traditional prejudices and jealousies, its narrow loyalties to the interests of any one arm, and in place thereof seizing upon a new earnest devotion to the Army and a spirit which will jump to the support of any branch of the service.

The Army must awake, face the new direction and take this new step. The past must be buried. Bygones must be bygones. The Army must get together, stand together, and then hold the positive spirit of accomplishment—"Let's go!"

To do this, elements of friction, inequality and injustice must be eliminated. It is futile to say we will have no friction in future and at the same time to harbor the seeds of friction.

Unity must include *all branches* of the services. No arm may be overlooked or conspired against without surely wrecking the strength of the whole. If there be one branch of the service, even though it be small and an auxiliary arm of limited scope, which yet is denied its just prestige and recognition, and by combination among other arms is subjected to discrimination and repression, such an arm will be a humanly inevitable source of poison. Too generally officers in one branch of the service lack specific acquaintance with the problems and technique of other arms of the service. It is then so easy to jump from ignorance of the other fellow's work to the conclusion that the other fellow's work is not worth while. There is this much to remember—the more earnestly do all arms and corps devote themselves each to the development of their own fields of effort, the more highly specialized will become the technique of each arm of the service, and hence the more unlikly that each will keep touch with the work of the other. Therefore, though it be desirable that every officer should be reasonably familiar with the work of all arms of the service, yet to practice this condition will become increasingly impossible. Nevertheless, in the interest of mutual confidence, it is imperative that every officer, lacking

specific knowledge of another's work, should assume that the other's work is as important and worth while as his own.

Again, there will recur in the future, as in the past, through the concurrence of circumstances, opportunities for officers in one service to seize a political or other advantage in which the Army as a whole will not share. In the development of the spirit of solidarity which is now foreshadowed, there must be a general acceptance of disdain for the advantage to be attained by any such means. Even if there remain individual officers who would not scorn to further their arm at the expense of the Army, the public opinion within each arm must spurn the acceptance of the advantage. Every arm of the services to varying extents has pursued selfish practices in the past. It may not be possible to wipe out all inequalities which the past has created, but every effort to do so must be made, and the record of the future kept clean.

Every arm of the services stands at the threshold of a new opportunity, which simultaneously has confronted the appreciation of each. The reactionaries will curl the cynical lip of doubt and will drag out all the old bogies of distrust and animosity. Of course, with no impulsion but doubt and distrust, neither this nor any other new spirit will go. What is needed is the pouring forth of the same flood of fresh courage and confidence which made our armies in France invincible, the union of all officers whose spirit says—"Can do!" and "Let's go!"

In order to promote esprit de corps and solidarity amongst professional engineers who are interested in the national defense, we are endeavoring at this time to form an Association or Society to which all such engineers will be eligible in some grade of membership. Such an organization appears also to be necessary if PROFESSIONAL MEMOIRS, our only regular medium for the exchange of ideas, is to continue to exist.

It is the intention to effect a preliminary organization amongst engineer officers now in the Regular Army and such others as held commissions as engineer officers in the forces of the United States, either at home or abroad, during the World War, and who can now be conveniently reached. Eventually provision will be made for membership to include all engineers and professional men who may be interested in the purposes of the Association.

In order to elicit opinion on this question, circulars were sent out some weeks ago to all engineer officers remaining in the service, and as this issue goes to press returns have been received from about 50 per cent of those addressed. These replies indicate an almost unanimous sentiment in favor of forming an association, and an overwhelming majority likewise favor a change in the name of this journal to something more truly representative of its purpose and scope. Those who have not yet sent replies are urged to do so without delay.

PROFESSIONAL MEMOIRS

Corps of Engineers, United States Army, and Engineer Department at Large

INDEX TO VOLUME XI.

JANUARY-DECEMBER, 1919.

I. Authors.

	Pages
Artillery Inspector, Ministry of War, French Army	305–307
American Expeditionary Forces, Ordnance Bulletin of	422–429
BAZZONI, C. B., Captain, Engineers	391–421
BEARD, C., Captain, Engineers, U. S. A.	47–64; 447–494
BLUNDON, MONTAGUE, Lieutenant, Engineers, U. S. A.	279–293; 543–570
BOND, AUBREY H., Captain, Engineers, U. S. A.	312–314
CAPLES, W. G., Colonel, Engineers, U. S. A.	650–674
CASSIDY, J. EDWARD, Lieutenant Colonel, Engineers, U. S. A.	253–258
COATES, A. B., Explosives Experiment Station	265–269
CRECELIUS, S. F., Lieutenant Colonel, Engineers, U. S. A.	757–760
CRESS, JAMES B., Lieutenant Colonel, Engineers, U. S. A.	139–149
DUCKERING, W. E., Captain, Engineers, U. S. A.	584–587
DUFFY, JAMES E., Chaplain, U. S. A.	348–350
ENGLAND, JAMES H., Lieutenant, Engineers, U. S. A.	128–133
GAEBLER, E. F., Captain, Engineers, U. S. A.	584–587
GODFREY, S. C., Colonel, Engineers, U. S. A.	571–580; 581–583
GREELEY, W. B., Lieutenant Colonel, Engineers, U. S. A.	742–750
GUPPY, B. W., Major, Engineers, U. S. A.	185–216
HALL, C. L., Col., Engineers, U. S. A.; Assoc. M. Am. Soc. C. E.	629–649

Pages

HAFERKORN, HENRY E., Librarian, Engineer School, U. S. A. xv–xvii; ix–xvii; ix–xx; xi–xviii; xi–xx; ix–xx

KULDELL, R. C., Lieutenant Colonel, Engineers, U. S. A. 229–248

LANAGAN, W. H., Lieutenant Colonel, Engineers, U. S. A. 714–729

LANGFITT, W. C., Major General, U. S. A. 138

LIPSEY, T. E. L., Assistant Engineer 65–122

LIVERMORE, W. R., Colonel, U. S. A., ret. 1–28; 123–127; 249–252

LYON, L. E., Lieutenant Colonel, Engineers 589–601

MILLIS, JOHN, Colonel, Engineers, U. S. A. 505–522

MONTGOMERY, W. J., Junior Explosives Engineer 260, 262; 263–264; 270–276

PERSHING, JOHN J., General, U. S. A. 137

PILLSBURY, G. B., Colonel, Engineers, U. S. A. 150–174; 675–694

PRATT, ARTHUR H., Engineer North Jersey District Water Supply Commission 730–741

PULLEN, D. D., Colonel, Tank Corps; Captain, Engineers, U. S. A. .. 751–756

RUBEL, A. C., Captain, Topographic Officer 294–304

SCHULZ, E. H., Colonel, Engineers, U. S. A. 325–347

SHAW, A. L., Captain, Engineers, Lecture by 430–442

SKELLY, J. W., Major, Engineers, U. S. A. 217–228

SPALDING, GEORGE R., Engineers, Lecture by 602–628

STICKLE, H. W., Lieutenant Colonel, Engineers, U. S. A. 695–713

SWIFT, HENRY, Major (Chaplain), U. S. A. 29–46

TIFFANY, J. E., Explosives Experiment Station 259

TRACY, EVARTS, Major, Engineers, U. S. A. 175–184

YOUNGBERG, G. A., Colonel, Engineers, U. S. A. 523–542

II. Subjects.

Pages

Ammunition Dumps 134–136

ANTI-AIRCRAFT SEARCHLIGHT—

Development of Anti-Aircraft Searchlight, The 139–149

ARTILLERY—

Pages

Accuracy of Sound Ranging Locations, Notes on.............. 391–421

Divisional Engineer Officer and His Relation to Artillery and Infantry.. 602–628

Fire and Effect of Modern Artillery.......................... 447–494

Flash and Sound Ranging Location Service, Final Report of... 351–383

High Burst Ranging.................................... 279–293

S. R. S. and F. R. S. Locations, Accuracy of.................. 384–390

Telemetric System of High Burst Ranging, The............... 543–570

BIBLIOGRAPHIES—

Articles of Engineering Interest........................... ix–xx

BIOGRAPHIES—

Beauregard, Pierre Gustave Toutant......................... 348–350

Cullum, George W.. 443–446

Foster, John Gray... 249–252

Mansfield, Jared 123–127

BRIDGES, MILITARY—

Bridging the Rhine with German Ponton Equipage............ 571–580

CAMOUFLAGE—

Camouflage Service of the United States Army, Memorandum on the.. 175–184

French Road Camouflage.................................. 528

CEMENT—

Puzzolana 430

ENGINEERING, MILITARY—

Barrier Type of Tank Defenses, The......................... 294–304

Bridging the Rhine with German Ponton Equipage............ 571–580

Divisional Engineer Officer and His Relation to the Artillery and Infantry, The.. 602–628

Engineer Troops in an Advance............................. 675–694

First Six Weeks on the Western Front, The.................. 629–649

Furnishing Timber for Military Operations.................. 742–750

Future Organization 495–504

German Mine for Wrecking Tanks........................... 305–307

German Traps and Land Mines............................. 277

Pages

Letter from Gen. John J. Pershing and Reply of Maj. Gen. W. C. Langfitt, A. 137–138

Operations of the Italian Engineers, Notes on 128–133

Technical Engineering Details of the Hindenburg Line in the Sector of Attack of the II Army Corps 175–184

Water Supply for a Field Army 730–741

Yperite Mines 308–311

ENGINEER ORGANIZATION—

Future Organization 495–504; 757–760

ENGINEER SCHOOL—

Engineer School at Camp A. A. Humphreys, Va., The 534–587

First Six Weeks on the Western Front, The 629–649

Proposed New Engineer School and Post and College of Military Research at Camp Humphreys, Va 714–729

EXPLOSIVES—

Adobe Shot with Grade III TNT on Boulder 259

Anti-Tank Mine 427–429

Blast and Pressure Meters and Tests of Explosives, Experiments with 325–347

Breaking Concrete Piers with Adobe Shots of Grade III TNT and 40 per cent Straight Glycerin Dynamite 265–269

Shot of Grade III TNT under Water, Report on 263–264

Tests to Demonstrate the Adaptability of Grade III TNT for Clearing Land, or Similar Uses, Report of 260–262

Tests to Determine the Adaptability of Grade III TNT for Shooting Oak Stumps, Report on 270–276

FLASH AND SOUND RANGING—

Accuracy of Sound Ranging Locations, Note on 391–421

Flash and Sound Ranging Service, Final Report of 351–383

S. R. S. and F. R. S. Locations, Accuracy of 384–390

FORTIFICATIONS—

Future of Permanent Fortifications, The 47–64

Improved Type of German Pill Box 253–258

Value of Permanent and Fortified Positions, Old and New Opinions about the 29–46

Pages

FUTURE ORGANIZATION 757–760

HINDENBURG LINE—

Reinforced Concrete Shelters of German Hindenburg Line..... 312–314

Technical Engineering Details of the Hindenburg Line in the Sector of Attack of the II Army Corps.......... 149–174

HISTORY—

Territorial History of Germany, Outline of the.......... 1–23

LAND MINES—

German Traps and Land Mines.......... 277

MAPPING, MILITARY—

Military Mapping Problem in the United States, The.......... 229–248

MILITARY ART—

First Six Weeks on the Western Front, The.......... 629–649

MILITARY BRIDGES—

Bridging the Rhine with German Ponton Equipage.......... 571–580

MILITARY RAILWAYS—

British Light Railways in France, A Technical Description of.. 185–216

MILITARY ROADS—

Engineer Troops in an Advance.......... 675–694

Roads in Supply and Attack.......... 650–674

MINES, MILITARY—

Barrier Type of Tank Defenses.......... 294–304

German Anti-Tank Mine.......... 422–425

German Mine for Wrecking Tanks.......... 305–307

German Traps and Land Mines.......... 277

Yperite Mine 308–311

MISSISSIPPI RIVER—

Currents At and Near Mouth, Southwest Pass.......... 65–122

ORGANIZATION, ENGINEER—

Future Organization 495–504

Organization of German Engineers, Notes on the.......... 581–583

RAILWAYS, MILITARY—

British Light Railways in France, A Technical Description of.. 185–216

RANGING—

Pages

High Burst Ranging 279–293

High Burst Ranging, Telemetric System of 543–570

RIVER AND HARBOR IMPROVEMENT—

Currents At and Near Mouth, Southwest Pass, Mississippi River 65–122

Monongahela River Navigation 695–713

Natural Features of the South Atlantic Coast, with Special Reference to Savannah Harbor 505–522

ROADS, MILITARY—

Engineer Troops in an Advance 675–694

French Road Camouflage 528

Italian Road System 131–133

Notes on a Divisional Engineer Regiment in the Army of Occupation 751–756

Roads of France 523–542

Roads in Supply and Attack 650–674

War Material for Use of National Highways 588

SEARCHLIGHTS—

Development of Anti-Aircraft Searchlights, The 139–149

SUPPLY AND ATTACK—

Roads in Supply and Attack 650–674

VOLCANIC TUFF AND ITS USES 430–442

WATERWAYS—

Currents At and Near Mouth, Southwest Pass, Mississippi River 65–122

Italian Waterways 128–131

Natural Features of the South Atlantic Coast, with Special Reference to Savannah Harbor 505–522

WATER SUPPLY—

Engineer Troops in an Advance 675–694

Water Supply for a Field Army 730–741

WORLD WAR—

First Six Weeks on the Western Front, The 629–649

Notes on a Divisional Engineer Regiment in the Army of Occupation 751–756

Articles of Engineering Interest.

Compiled with a view to including articles of civil and military engineering subjects of special interest to the readers of PROFESSIONAL MEMOIRS, Corps of Engineers and Engineer Department at Large. By Henry E. Haferkorn, Librarian, Engineer School.

The following abbreviations are used, viz:

Am. I. M. E.—American Institute of Mining Engineers, N. Y. Transactions Bulletin.

Am. Soc. M. E. J.—American Society of Mechanical Engineers, New York City. Journal.

Boston Soc. C. E. J.—Boston Society of Civil Engineers, Boston, Mass. Journal.

Ca. E.—Canadian Engineer, Toronto, Ontario, Canada.

Eng. C. W.—Engineering and Cement World, Chicago.

Eng. C.—Engineering and Contracting, Chicago.

Eng. C. St. L.—Engineers' Club of St. Louis, Mo. Journal.

Eng. & Min. J.—Engineering and Mining Journal, New York. Weekly.

Engi.—The Engineer, London. Weekly, v. 1, 1856.

Gen. Elect. R.—General Electric Review, Schenectady, N. Y.

N. E. Wat. A.—New England Waterworks Association, Boston. Journal.

Sci. Am.—Scientific American, New York.

Soc. Autom. E.—Society of Automotive Engineers New York. Transactions.

AMBULANCE TRAINS.

An ambulance train for the American army. (Engi.), Sept. 27, 1918, p. 260-262, incl. 6 fig. (half-tones, diagrs., etc.). See half-tones, p. 266, and plans, sects., etc., p. 263.

ARCHES.

Direct design of curvature of arches. (Ca. E.), Oct. 31, 1918, p. 379-381, incl. 4 figs. (tables, sects., etc.).

AVIATION.

Translantic flight. (Soc. Autom. E.) Nov., 1918, p. 319-321.

BRIDGES.

Mechanical features of the vertical-lift bridge. Horatio P. van Cleve. (Am. Soc. M. E.) Nov., 1918, p. 938-941, incl. 8 half-tones.

Mystic River bridge. Description of superstructure. John C. Moses. (Boston Soc. C. E. J.) Oct., 1918, p. 379-385, incl. 6 half-tones.

Notes on the construction of the Mystic River bridge, Everett extension of the Boston Elevated Railway Company. Clarence T. Fernald. (Boston Soc. C. E. J.), Oct., 1918, p. 367-378, incl. 10 figs. (half-tones, elevations, etc.).

(Prepared for PROFESSIONAL MEMOIRS, v. 11, No. 55, January-February, 1919.)

CONCRETE PAVEMENTS.

Vertical movements in concrete pavements and a suggestion towards their elimination. J. W. Lowell. (Eng. C.) Nov. 6, 1918, p. 441-443, incl. 3 figs. (tables, charts, diagrs.).

CONSERVATION.

Saving of water and conservation of coal. Geo. A. Carpenter. (N. E. Wat. A.), Sept., 1918, p. 198-203.

ELECTRODES.

Electrodes for electric furnaces; their manufacture, properties and utilization. J. Escard. (Gen. Elec. R.), Oct., 1918, p. 664-671, incl. 9 figs. (tables, sections, etc.); Nov., 1918, p. 781-792, incl. 31 figs. (tables, sections, etc.).

HAULAGE.

Industrial tractors for solving freight terminal congestion. (Eng. C. W.), Nov. 1, 1918, p. 38-42, incl. 3 figs. (half-tones, plans).

MOTOR CARS AND TRUCKS.

The motor truck as an aid to business profit. S. V. Norton. (Soc. Autom. E.), Nov., 1918, p. 309-316, incl. 4 figs. (half-tones, tables).

PIPES—LEAKS.

Practical method for detecting leaks in underground pipes. D. A. Hefferman. (N. E. Wat. A.), Sept., 1918, p. 204-216.

POWDERED COAL.

The use of coal in pulverized form. H. R. Collins. (Am. I. M. E.), April, 1918, p. 955-961.

RESEARCH.

New Westinghouse research building. (Eng. & Min. J.), Nov. 16, 1918, p. 886.

Organization of industrial research. Arthur D. Little. (Eng. C., St. L.), Sept., 1918, p. 269-277.

Scientific and industrial researches. (Engi.), Sept. 27, 1918, p. 272-273.

I. Industrial research associations.
- Fuel research board.
- Peat inquiry committee.
- Mine rescue apparatus.
- Tin and tungsten research board.
- Timber research (building material).

II. Aided researches in progress.
- New aided researches.
- Grants to students and research workers.

SEARCHLIGHTS.

Providing the searchlight with ears. (Sci. Am.), Nov. 9, 1918, p. 379. 160 words and 1 half-tone.

Articles of Engineering Interest.

Compiled with a view to including articles of civil and military engineering subjects of special interest to the readers of PROFESSIONAL MEMOIRS, Corps of Engineers and Engineer Department at Large. By Henry E. Haferkorn, Librarian, Engineer School.

The following abbreviations are used, viz:

Am. Arch.—American Architect, N. Y.
Am. Gas Eng. J.—American Gas Engineering Journal, N. Y.
Am. Gas L. J.—American Gas Light Journal, N. Y.
Am. I. E. E.—American Institute of Electrical Engineers, N. Y. Proceedings.
Am. Inst. Arch.—American Institute of Architects, Washington, D. C. Journal.
Am. I. M. E.—American Institute of Mining Engineers, N. Y. Bulletin.
Am. Mach.—American Machinist, N. Y.
Am. Soc. C. E. P.—American Society of Civil Engineers, N. Y. Proceedings.
Am. Soc. M. E.—American Society of Mechanical Engineers, N. Y. Journal.
Am. Water W. A.—Am. Water Works Assoc'n., N. Y. Journal.
Automobile.—Automombile, N. Y., now Automotive Industries, N. Y.
Autom. Ind.—Automotive Industries N. Y.
Boston Soc. C. E. J.—Boston Society of Civil Engineers, Boston. Journal.
Ca. E.—Canadian Engineer, Toronto, Canada.
Chem. & Met. Eng.—Chemical & Metallurgical Engineering, New York.
Coal Age.—Coal Age, N. Y.
Com. Veh.—Commercial Vehicle, New York.
Dom. Eng.—Domestic Engineering, Chicago.
Elec. R.—Electrical Review, Chicago.
Elec. W.—Electrical World, N. Y.
Engi.—The Engineer, London.
Eng. C.—Engineering and Contracting, Chicago.
Eng. C. P.—Engineers Club of Philadelphia, Pa., Proceedings.
Eng. M. J.—Engineering and Mining Journal, N. Y.
Eng. N.—Engineering News, N. Y.
Eng. N.—Engineering News-Record, New York.
Eng. R.—Engineering Record, N. Y.
Eng. W.—Engineering World, Chicago; formerly Engineering and Cement World and Cement Era.
Foundry—Foundry, Cleveland, Ohio.
Frank. I.—Franklin Institute, Philadelphia, Pa. Journal.
Gas Age.—Gas Age, N. Y.
Gen. Elec. R.—General Electric Review, Schenectady, N. Y.
Heat & Ven.—Heating & Ventilating Magazine, N. Y.
Horseless Age—Horseless Age, N. Y.
Illum. Eng.—The Illuminating Engineer, London.
Ind. Manag.—Industrial Management, N. Y.
Inf. J.—Infantry Journal, Washington, D. C.
Inst. E. E. J.—Institution of Electrical Engineers, London. Journal.
Int. Marine Eng.—International Marine Engineering, N. Y.
Iron Age.—Iron Age, N. Y.
Iron Tr. R.—Iron Trade Review, Cleveland, Ohio.
J. Ind. E. Chem.—Journal of Industrial and Engineering Chemistry, Easton, Pa.
J. R. Art.—Journal, Royal Artillery, Woolwich, England.
Mach.—Machinery, N. Y.
Met. & Chem. Eng.—Metallurgical and Chemical Engineering, New York.
Met. Ind.—Metal Industry, New York.
Metal Work.—Metal Worker, Plumber & Steam Fitter, N. Y.
Munic. Eng.—Municipal and Country Engineering, Indianapolis, Ind.
Munic. J.—Municipal Journal, N. Y.
Power.—Power, New York.
R. Eng. J.—Royal Engineers Journal, Chatham, England.
Rev. M. Suisse.—Revue Militaire Suisse, Lausanne, Switzerland.
R. U. S. I. L.—Royal United Service Institution, London. Journal.
Ry. Age.—Railway Age, N. Y. Formerly Railway Age Gazette.
Ry. R.—Railway Review, Chicago.
Sci. Am.—Scientific American, New York.
Sci. Am. S.—Scientific American Supplement, New York.
Sibley.—Sibley Journal of Engineering, Ithaca, N. Y.
Soc. Autom. E.—Society of Automotive Engineers, New York.
Soc. Autom. E.—Society of Automotive Engineers, New York.
S. P. Eng. E.—Society for the Promotion of Engineering Education. Proceedings.
U. Eng. Exp. Sta. Bul.—University of Illinois, Urbana, Ill. Engineering Experiment Station. Bulletin.
U. S. Nat. Advis. Com.—United States National Advisory Committee for Aeronautics, Washington, D. C.
W. Soc. E. J.—Journal of Western Society of Engineers, Chicago, Ill.

(Prepared for PROFESSIONAL MEMOIRS, v. 11, No. 56, March-April, 1919.)

AMMUNITION.

The design of artillery ammunition and some recent developments at Frankford Arsenal. J. Wallace Taylor. (Eng. C. P.), April, 1919, p. 127-137, incl. 8 figs. (1 half-tone, 7 sections, etc.)

Paper presented by author before the Technology Club of Philadelphia, January 7, 1919, at the Engineers' Club.

A general outline of the principles and data involved in the design of artillery ammunition, including a discussion of explosives, guns, projectiles and fuzes, with a brief statement of the work of the Frankford Arsenal.

BRIDGES—PIERS. *See also* CAISSONS.

Bridge substructure construction with concrete caissons sunk by open excavation method. (Eng. C.), March 26, 1919, p. 317-319, incl. 3 figs. (sections, etc.).

The article is taken from an interesting discussion by Mr. L. W. Skov, Assistant Engineer, Bridge Department, of his experiences with concrete caissons in bridge foundation work for the Chicago, Burlington & Quincy Railroad. Mr. Skov's paper was presented before the Western Society of Engineers.

CAISSONS.

Concrete caissons sunk by the open dredging method. L. W. Skov. (W. Soc. E. J.), June, 1918, p. 383-407, incl. Sections, plans and diagrams.

CALCULUS.

The meaning of integration in calculus. James E. Boyd. (S. P. Eng. E.), v. 24, 1916, p. 319-327, incl. diagrs.

CAMS.

Cam design and construction. F. De R. Furman (Am. Mach.), March 27, 1919, p. 581-586, incl. 13 figs. (sections, etc.).

This series of articles is presented with a view to placing before the reader the whole subject of cam design on a systematic scientific basis.

CEMENT—CONCRETE. *See also* SUBAQUEOUS CONCRETE.

Effect of quantity of mixing water and curing conditions on the strength and wear of concrete. (Eng. C.), March 26, 1919, p. 309-312, incl. diagrs.

A review of recent experimental studies made by Professor Duff A. Abrams of the Lewis Institute, Chicago, on the effect of water content and curing conditions on the compression strength and wearing resistance of concrete.

CHESSES. *See* MILITARY BRIDGES—MATERIAL.

CIVIL ENGINEERING—STUDY AND TEACHING.

Report on civil engineering. (S. P. Eng. E.), v. 24, 1916, p. 200-209, incl. tables.

The tables contain answers to a questionnaire sent out by the Committee on the subject.

DAMS.

The East Canyon Creek dam. A. F. Parker. (Am. Soc. C. E. P.), March, 1919, p. 93-113, incl. sections, plans and tables.

DRAWING—STUDY AND TEACHING.

Coördinating drafting and shopwork. F. G. Higbie. (S. P. Eng. E.), v. 23, 1915, p. 175-192.

EAST CANYON CREEK DAM. *See* DAMS.

ELECTRICAL ENGINEERING—STUDY AND TEACHING.

Report of Committee on electrical engineering. C. F. Scott. (S. P. Eng. E.), v. 24, 1916, p. 221-228.

ELECTRIC WELDING.

Electric seam welding. P. T. Van Bibber. (Am. Mach.), March 27, 1919, p. 575-580, incl. 14 figs. (half-tones, diagrs.), tables i, ii.

Few mechanics, outside of the manufacturing concerns employing electric-seam welding machines, realize the importance or method of operation. The machines and applications here shown will clearly indicate the field that is covered.

ENGINEERING—ESSAYS, ETC.

The human side of engineering. F. H. Newell. (S. P. Eng. E.), v. 24, 1916, p. 333-336.

ENGINEERING—NOMENCLATURE. *See* ENGINEERING—TERMINOLOGY.

ENGINEERING PROBLEMS—COMPETITION.

The annual competition conducted by the Engineers' Society of Western Pennsylvania. J. H. Leete. (S. P. Eng. E.), v. 23, 1915, p. 120-127.

ENGINEERING—RESEARCH.

Research as an element of the growth and progress of the school. (S. P. Eng. E.), v. 24, 1916, p. 284-303.

ENGINEERING—STUDY AND TEACHING.

Class and laboratory work in engineering. Wm. C. Bauer. (S. P. Eng. E.), v. 23, p. 106.

The education of the future engineer. C. L. Cory. (S. P. Eng. E.), v. 23, 1915, p. 86-98.

Reflections of a director. John F. Hayford. (S. P. Eng. E.), v. 23, 1915, p. 220-230.

The relation of the engineering schools to the profession, the state and the public. Anson Marston. (S. P. Eng. E.), v. 23, 1915, p. 56-69.

Report of progress in the study of engineering education. C. R. Mann. (S. P. Eng. E.), v. 23, 1915, p. 70-85; v. 24, 1916, p. 48-97.

Some details in engineering education. Henry S. Jacoby. (S. P. Eng. E.), v. 24, 1916, p. 27-42.

Some important questions in engineering education. J. A. L. Waddell. (S. P. Eng. E.), v. 23, 1915, p. 207-219.

Some thoughts on engineering education. A. B. McDaniel. (S. P. Eng. E.), v. 24, 1916, p. 328-332.

The value of final examinations. E. D. Walker. (S. P. Eng. E.), v. 23, 1915, p. 204-206.

ENGINEERING—TERMINOLOGY.

Preliminary report of the Committe on the standardization of technical nomenclature. (S. P. Eng. E.), v. 23, 1915, p. 349-369; v. 24, 1916, p. 241-283.

ENGINEER TROOPS—DEMOBILIZATION OF REGIMENTS.

Demobilization of Engineer Regiments. Brig. Gen. Fred. V. Abbot, Engineers. (Eng. C.), March 26, 1919, p. 303.

Why engineering regiments should be mustered out at once. (Eng. C.), March 5, 1919, p. 232.

ENGLISH LANGUAGE—STUDY AND TEACHING.

Report of the Committee on English. C. W. Park. (S. P. Eng. E.), v. 24, 1916, p. 177-193.

EUROPEAN WAR, 1914-18.

1815 and 1918. W. D. Bird. (R. U. S. I. L.), February, 1919, p. 92-97.

EUROPEAN WAR, 1914-18.—THE ARMISTICE.

The Armistice. (R. U. S. I. L.), February, 1919, p. 110-121.

EUROPEAN WAR, 1914-18.—BATTLE OF TANNENBERG.

The campaign of 1914 in East Prussia. T. E. Compton. (R. U. S. I. L.), February 1, 1919, p. 74-91. 1 map.

EUROPEAN WAR, 1914-18.—ENGINEER SERVICE.

With the divisional engineers in a great offensive. Chas. E. De Leuw. (Eng. N.), April 3, 1919, p. 656-658.

What the fighting Engineer troops had to do when they went ahead day by day with the infantry.

The author is a member of the firm of Gates & DeLeuw, Engineers, Chicago, and served as Captain Engineers in the war.

Contents: Division Engineers' part in trench fighting. When our Engineer units first saw real fighting in the open. Repairing roads "for a rest." Met machine guns, shells and gas.

EUROPEAN WAR, 1914-18.—ENGINEER SERVICE—GT. BRITAIN.

The Royal Engineers of the Irish division. R. F. A. Butterworth. (R. Eng. J.), March, 1919, p. 103-116.

Work by R. E. units in the war. (R. Eng. J.), March, 1919, p. 89-102.

EUROPEAN WAR, 1914-18.—MILITARY RAILROADS.

Standard gauge railway work at the front. (Ca. E.), March 20, 1919, p. 309-311, incl. 4 half-tones, 1 chart.

Pioneer truck **Minesweeper** used by 277th Construction company in rebuilding the main line of the North Railway to Lille—in one day laid 2.5 miles of track and one turnout over badly wrecked roadbed.

FACTORY MANAGEMENT.

Methods of teaching industrial management at the University of Kansas. P. F. Walker. (S. P. Eng. E.), v. 23, 1915, p. 137-149.

FATIGUE OF METALS.

The fatigue of metals. H. F. Moore. (Eng. C. P.), April, 1919, p. 138-143, incl. 10 figs. (half-tones, sections, etc.).

Paper presented before the Engineers' Club of Philadelphia, February 15, 1919.

Author is research professor of engineering materials, University of Illinois; Chairman National Research Council, Committee on fatigue phenomena in metals.

Contents: The characteristics of fatigue failure. Correlation of stress and life under fatigue. Proposed formulas for failure stress calculations. Effect of range of stress on resistance to fatigue. Criteria of fatigue resisting strength. Effect of cold-working of material and of heat treatment. Work of the National Research Council.

FLOODS AND FLOOD CONTROL.

The Miami conservancy flood prevention plan. W. A. Drake. (Sci. Am.), March 22, 1919, p. 282-299, incl. 2 half-tones, 1 plan.

FORTIFICATION.

Future of permanent fortification. (R. Eng. J.), March, 1919, p. 152-154.

FOUNDATIONS. *See also* CAISSONS.

HAULAGE.

Hauling goods overland between Dallas and Fort Worth proves successful. J. Husson. (Com. Veh.), March 15, 1919, p. 5-9, incl. 3 half-tones, and 3 charts.

Fleet of thirteen trucks and several trailers meet needs of two thriving cities of great southwest.

HYDRAULICS—STUDY AND TEACHING.

Report of Committee on mechanics and hydraulics. E. R. Mauer. (S. P. Eng. E.), v. 24, 1916, p. 194-197.

LIGHTING—STUDY AND TEACHING.

Instruction in illuminating engineering. L. B. Spinney. (S. P. Eng. E.), v. 23, p. 99-105.

MATHEMATICS—STUDY AND TEACHING.

Report of Committee on mathematics. L. C. Plant. (S. P. Eng. E.), v. 24, 1916, p. 143-158.

MECHANICAL ENGINEERING—STUDY AND TEACHING.

Report of Committee on mechanical engineering. A. M. Greene, Jr. (S. P. Eng. E.), v. 24, 1916, p. 210-220.

MECHANICS—STUDY AND TEACHING.

Report of the Committee on the Teaching of Mechanics to Students of Engineering. (S. P. Eng. E.), v. 23, 1915, p. 241-311, incl. diagrs.

Report of Committee on mechanics and hydraulics. E. R. Maurer. (S. P. Eng. E.), v. 24, 1916, p. 194-197.

MILITARY BRIDGES—MATERIAL.

Jointed chesses. G. R. Percy. (R. Eng. J.), March, 1919, p. 135-139, incl. sections and plans.

MILITARY RAILROADS. *See also* EUROPEAN WAR, 1914-18.—MILITARY RAILROADS.

NOMOGRAPHY.

What is a nomogram? R. K. Hezlet. (J. R. Art.), January, 1919, p. 330-333, 2 tables.

ORDNANCE.

How ordnance is inspected—II. F. H. Colvin. (Am. Mach.), March 20, 1919, p. 557-563, incl. 3 half-tones.

PACK TRANSPORTATION.

A field company on pack transport. G. C. Sanford. (R. Eng. J.), March, 1919, p. 117-134, incl. 5 figs and tables.

Methods employed by the 2nd Wessex Field Company, R. E. (T. F.).

PHYSICS—STUDY AND TEACHING.

Report of Committee on the teaching of physics to students of Engineering. (S. P. Eng. E.), v. 23, 1915, p. 312-323, v. 24, 1916, p. 159-176.

RADIO COMPASS.

The Wireless compass. J. Lachenbruch. (Sci. Am.), March 22, 1919, p. 291; 306. 2 figs.

Piloting ships into port by radio.

ROADS.

Roads. A. G. T. Cusins. (R. Eng. J.), March, 1919, p. 144-151.

ROYAL ENGINEERS. *See* EUROPEAN WAR, 1914-18.

SCREW THREADS. *See also* PIPE THREADS.

National Screw Thread Commission. (Soc. Autom. E.), February, 1919, p. 94-96.

SEA MINES.

The North Sea mine barrage. ii. R. R. Belknap. (Sci. Am.), March 22, 1919, p. 288-289, incl. 5 half-tones, 3 diagrs.

SEARCHLIGHTS.

Searchlight problems of military importance. Chester Lichtenberg. (Elec. W.), September 7, 1918, p. 454; the same (Illuminating Engineer), October, 1918, p. 238.

SEATTLE, WASH.—HARBOR. *See* HARBORS—U. S.

SEA WALLS.

Coastal and shore protection. H. C. Campbell. (Eng. W.), Feb. 15, 1919, p. 11-17, incl. 11 half-tones, 7 figs.

Construction of breakwaters and sea walls varies with location and conditions—revetment work is similar to concrete pavement.

SEWAGE DISPOSAL.

Sewage disposal works at London, Ont. W. Chinman. (Ca. E.), March 6, 1919, p. 269-274, incl. 5 half-tones, plans, sections, etc.

SEWERAGE.

San Francisco's sewage system. W. A. Scott. (Eng. W.), February 1, 1919, p. 14-16, incl. 4 half-tones.

SHIPBUILDING.

The fabricated ship in America. (Engi.), Dec. 20, 1918, p. 523-524, incl. 11 half-tones.

SHIPPING.

Some problems in shipping. C. M. Ripley. (Gen. Elec. R.), January, 1919, p. 82-88, incl. half-tones.

SHORE PROTECTION.

San Francisco's protected beach. (Eng. W.), March 1, 1919, p. 33-35, incl. 8 figs.

SINGAPORE—HARBOR. *See* HARBORS—STRAITS SETTLEMENTS.

SNOW REMOVAL.

Electric railway snow fighting equipment and its application. (Eng. C.), January, 1919, p. 68.

Methods of removing snow from highways. (Eng. C.), March 5, 1919, p. 239-241.

SOLDIERS—INTELLIGENCE TESTS.

Army mental tests. (Inf. J.), February, 1919, p. 626-635, incl. examples, etc.

STRENGTH OF MATERIALS. *See also* FATIGUE OF METALS.

STRUCTURES, THEORY OF.

On a new principle in the theory of structures. G. F. Swain. (Am. Soc. C. E. P.), March, 1919, p. 75-91.

SUBAQUEOUS CONCRETE.

Methods of depositing concrete under water. (Eng. C.), March 26, 1919, p. 307-308.

The article consists of data presented by a committee on masonry at the annual convention of the American Railway Engineering Association, and representing in its opinion, the best practices to be followed in depositing concrete under water.

TACTICS.

Future tactics. A. L. Schreiber. (R. Eng. J.), March, 1919, p. 140-143.

TECHNICAL TERMS. *See also* ENGINEERING—TERMINOLOGY.

THERMODYNAMICS—STUDY AND TEACHING.

Engineering thermodynamics at American colleges. A. A. Potter. (S. P. Eng. E.), v. 23, 1915, p. 128-136.

U. S. ARMY—ORGANIZATION.

La transformation de l'armée des Etats-Unis. (Rev. M. Suisse), Janvier, 1919, p. 5-24.

WELDING.

Modern welding and cutting. E. Viall. (Am. Mach.), March 20, 1919, p. 529-532, incl. figs. 64-74.

vi. Thermit-welding compromise rail joints.

This article not only shows how to weld various types of rail joints, but contains hints for the practical mechanic, which may enable him to execute special repair jobs in the machine shop.

WOODWORKING—STUDY AND TEACHINGS.

Woodworking for mechanical engineering students. A. S. Kinsey. (S. P. Eng. E.), v. 23, 1915, p. 150-174, incl. half-tones, diagrs., sections, etc.

Articles of Engineering Interest.

Compiled with a view to including articles of civil and military engineering subjects of special interest to the readers of PROFESSIONAL MEMOIRS, Corps of Engineers and Engineer Department at Large. By Henry E. Haferkorn, Librarian, Engineer School.

The following abbreviations are used, viz:

Am. I. M. E.—American Institute of Mining Engineers. N. Y. Transactions. Bulletin.

Am. Soc. Heat. & V. E.—American Society of Heating and Ventilating Engineers, N. Y. Journal.

Am. Soc. M. E. J.—American Society of Mechanical Engineers, New York City. Journal.

Autom. Ind.—Automotive Industries, The Automobile, New York.

Boston Soc. C. E. J.—Boston Society of Civil Engineers, Boston Mass. Journal.

Bull. T. S. R.—Bulletin De la Suisse romande, Lausanne.

Ca. E.—Canadian Engineer, Toronto, Ontario, Canada.

Eng.—Engineering, London.

Eng. C. W.—Engineering and Cement World, Chicago.

Eng. C.—Engineering and Contracting, Chicago.

Eng. C. St. L.—Engineer's Club of St. Louis, Mo., Journal.

Eng. M. J.—Engineering and Mining Journal, New York.

Eng. S. W. P.—Engineers' Society of Western Pennsylvania, Pittsburg. Proceedings.

Engi.—The Engineer, London.

Gen. Elec. R.—General Electric Review, Schenectady, N. Y.

Génie C.—Le Génie Civil, Paris.

N. E. Wat. A.—New England Water Works Association, Boston, Mass.

Power—Power, New York.

P. Eng.—Practical Engineer, London.

Prof. M.—Professional Memoirs, Washington Barracks, D. C.

Sci. Am.—Scientific American, New York.

Sci. Am. S.—Scientific American Supplement, New York.

Soc. Autom. E.—Society of Automotive Engineers, New York. Transactions.

W. Soc. E. J.—Western Society of Engineers, Chicago. Journal.

AERONAUTICS, MILITARY.

Airplane bombing. (Soc. Autom. E.), Nov., 1918, p. 323-324, incl. 2 half-tones. Extracts from diary of von Richthofen. (Autom. Ind.) 1. Nov. 14, 1918. p. 827-830. incl. 7 half-tones, Nov. 21, 1918, p. 878-881, incl. 11 halftones.

Training our aerial bombers. (Sci. Am.), Oct. 26, 1918, p. 336-337, incl. 9 half-tones.

AEROPLANES.

The Pfalz single-seater biplane. (Engi.), Sept. 27, 1918, p. 270-273, incl. 21 diagrs.

The Zeppelin Biplane. Jean Lagorgette. (Sci. Am. S.), Nov. 16, 1918, p. 316-319, incl. 3 diagrs.

AMBULANCE TRAINS.

An ambulance train for the American army. (Engi.), Sept. 27, 1918, p. 260-262, incl., 6 fig. (half-tones, diagrs. etc.) See half-tones p. 266 and plans, sections, etc. p. 263.

AMONIA OXIDATION. *See* CHEMISTRY, TECHNICAL.

ARCHES.

Direct design of curvature of arches. (Ca. E.), Oct. 31, 1918, p. 379-381, incl. 4 figs. (tables, sections, etc.)

ASPHYXIATING GAS.

L'Emploi des gaz asphyxiants à la guerre en Allemagne au xve siècle. Génie C.), Oct. 5, 1918, p. 274-275.

AVIATION.

Trans atlantic flight. (Soc. Autom. E.), Nov., 1918, p. 319-321.

BAFFLES, STEAM-BOILERS. *See* STEAM-BOILERS.

BALKAN PENINSULA,—WAR, 1914. *See* EUROPEAN WAR, 1914-1918. BALKAN

PENINSULA.

BALLISTICS.

The elliptic trajectory over the earth. G. Greenhill. (Eng.), Oct. 11, 1918, p. 393-395, incl. 3 figs.; Oct. 18, 1918, p. 424-427, incl. 1 fig.

BARGES.

More concrete sea-going barges launched. (P. Eng.), Oct. 3, 1918, p. 161.

BRIDGES.

Mechanical features of the vertical-lift bridge. Horatio P. van Cleve. (Am. Soc. M. E.), Nov., 1918, p. 938-941, incl. 8 half-tones.

Mystic River bridge. Description of superstructure. John C. Moses. (Boston Soc. C. E. J.), Oct., 1918, p. 379-385, incl. 6 half-tones.

Notes on the construction of the Mystic River bridge, Everett extension of the Boston Elevated Railway Company. Clarence T. Fernald (Boston Soc. C. E. J.), Oct., 1918, p. 367-378, incl. 10 figs. (half-tones, elevations, etc.)

The principal bridges of the world. I. (Sci. Am. S.), Nov. 2, 1918, p. 286-288.

CAISSONS.

See under BRIDGES—FOUNDATIONS.

CANALS—FRANCE.

Project de canal de Paris à Dieppe. (Génie C,), Oct. 5, 1918, p. 271-273, incl. 4 figs. (maps, sections.)

CARRIER PIGEONS.

The dove of war. Lee S. Crandall. (Sci. Am. S.), Nov. 3, 1918, p. 276, incl. 2 half-tones.

CEMENT—CONCRETE.

Iron cement. (Eng. C. W.), Nov. 1, 1918, p. 32-34.

Pneumatic method of concreting. H. B. Kirkland. (W. Soc. E. J.), May, 1918, p. 319-355, incl. 2 fig. (half-tones, diagrs, sections, elevations, tables, etc.)

Report of laying concrete in freezing weather. D. A. Watt. (Prof. M.), Sept.-Oct., 1918, p. 622-626, incl. 3 fig. (half-tones, elevations).

CHEMISTRY.

Electricity releases chemistry's power. Jas. M. Matthews, (Gen. Elec. R.), Nov., 1918, p. 727-750, incl. 46 half-tones. ,

CHEMISTRY, TECHNICAL.

Development in nitric acid manufacture in the United States since 1914, E. J. Pranke. (Gen. Elec. R.), Nov., 1918, p. 804-806, incl. 1 table.

Starting and stability phenomena of amonia oxidation and similar reactions. F. G. Liljenroth. (Gen. Elec. R.), Nov., 1918, p. 807-815, incl. 8 figs. (tables, scales, etc.)

CONCRETE PAVEMENTS.

Vertical movements in concrete pavements and a suggestion towards their elimination. J. W. Lowell. (Eng. C.), Nov. 6, 1918, p. 441-443, incl. 3 figs. (tables, charts, diagrs.)

CONCRETE ROADS. *See* ROADS, CONCRETE.

CONCRETE SHIPS.

Design and construction features of reinforced concrete vessels. (Eng. C.), Oct. 30, 1918, p. 409-413, incl. 10 figs. (half-tones, diagrs., sections, etc.)

Reinforced concrete vessels. W. Pollock. (Ca. E.), Oct. 24, 1918, p. 367-373, incl. 5 figs. (tables, diagrs., etc.)

Report of the special committee of the Engineers' club on construction of concrete ships in St. Louis. (Eng. C., St. L.), Sept., 1918, p. 302-304.

CONSERVATION.

Saving of water and conservation of coal. Geo. A. Carpenter, (N. E. Wat. A.), Sept., 1918, p. 198-203.

CORROSION.

See also under HOUSE DRAINAGE.

DIESEL ENGINE. *See* GAS ENGINES.

DIVING BELLS. *See* SALVAGE.

ELECTRIC FURNACES. *See* also METALLURGY.

Nitrogen fixation furnaces. E. Kilburn Scott. (Gen. Elec. R.), Nov., 1918, p. 799-804, incl. 16 figs. (section, tables, etc.)

Electric furnaces for the production of steel and ferro-alleys. J. A. Seede, (Gen. Elec. R.), Nov., 1918, p. 767-780, incl. 29 figs. (half-tones, designs, tables, etc.)

ELECTRODES.

Electrodes for electric furnaces; their manufacture, properties and utilization. J. Escard. (Gen. Elec. R.), Oct., 1918, p. 664-671, incl. 9 figs. (tables, sections, etc.); Nov., 1918 p. 781-792, incl. 31 figs. (tables, sections, etc.)

ELECTROLYTIC PROCESSES.

Electrolytic and electrothermic processes and products. (Gen. Elec. R.), Nov., 1918, p. 756-766, incl. 14 figs. (sections, tables, elevations, etc.)

ELECTROTHERMIC PROCESSES.

See under ELECTROLYTIC PROCESSES.

ENGINEERING-CONTRACTS.

Equitable war period contract form. F. J. Weinert. (Eng. C., St. L.), Sept. 1918, p. 278-291.

EUROPEAN WAR—1914-1918.

From peace to war, from war to victory, from victory to just judgment. William T. Sedgwick. (N. E. Wat. A.), Sept., 1918, p. 189-197.

EUROPEAN WAR, 1914-1918.—ARTILLERY.

The man behind the guns. C. H. Claudy. (Sci. Am.), Nov. 9, 1918, p. 376-377, incl. 8 half-tones.

EUROPEAN WAR, 1914-18.—BALKAN PENINSULA.

The Balkan theatre of war. D. W. Johnson. (Prof. M.), Sept.-Oct., 1918, p. 633-664, incl. 10 fig. (half-tones, maps, etc.)

EUROPEAN WAR, 1914-18—ORDNANCE.

Artillery which keeps pace with the infantry. (Sci. Am.), Nov. 2, 1918, p. 252-253, incl. 5 half-tones.

EUROPEAN WAR, 1914-18.—RECONSTRUCTION.

The state and reconstruction. Editorial. (Engi.), Oct. 11. 1918, p. 309.

Industrial reconstruction. Editorial. (Eng.), Oct. 18, 1918, p. 437-438.

EXPLOSIVES. *See* also CHEMISTRY.

FERRO-ALLOYS.

See METALLURGY. *See* also ELECTRIC FURNACES.

FILTERS AND FILTRATION.

Drifting sand filter, Toronto Island. Col. G. G. Nasmith. (Ca. E.), Oct. 24, 1918, p. 359-364, incl. 9 figs. (half-tones, tables, etc.)

FORTIFICATIONS.

Fortifications as dependent upon advance in human knowledge. C. T. Sacket. (Prof. M.), p. 693-715, Sept.-Oct., 1918, incl. 20 figs. (half-tones, sketches, etc.)

Old and new opinions about the value of permanent and fortified positions. (Prof. M.), July-Aug., 1918, p. 525-548, incl. 1 sketch; Sept.-Oct., 1918, p. 664-692.

FOUNDATIONS.

Foundations built of rock filling in concrete for engines, generators and motors. L. J. Keith (Eng. C. W.), Nov. 1, 1918, p. 30, incl. 2 sections.

Foundation construction. (Eng. C. W.) p. 11-13, incl. 9 half-tones.

GAS ENGINES. *See* also GOVERNORS.

Discussion of certain problems in regard to marine Diesel oil engines, John W. Anderson. (Am. Soc. M. E.), Nov., 1918, p. 299-308, incl. 5 diagrs. To be concluded.

GOVERNORS.

The design of governors, with special reference to small Diesel engines. Arthur B. Lakey. (Eng. S. W. P.), July, 1918, p. 461-488 incl. 14 plans.

HARBORS—CANADA.

Will plan development of Vancouver Harbor. (Ca. E.), Oct. 31, 1918, p 393-394, incl. 1 sketch.

HARBORS—EAST INDIA.

Indian sea ports. (Engi.), Oct. 18, 1918, p. 334-335.

HAULAGE.

Industrial tractors for solving freight terminal congestion. (Eng. C. W.) Nov. 1, 1918, p. 38-42, incl. 3 figs. (half-tones, plans.)

HEATING.

Relation of hot water service heating to various types of buildings. Harold L. Alt. (Am. Soc. Heat. & V. E.), Jan., 1918, p. 261-269, incl. 5 figs.

What we do and don't know about heating. John R. Allen. (Am. Soc. Heat & V. E.), Jan. 19, 1918, p. 271-277.

The engineering of warm air furnace heating. M. William Ehrlich. (Am. Soc. Heat. & V. E.), Apr., 1918, p. 395-411, incl. 11 figs. (half-tones, tables, etc.)

Economy in heating. Konrad Meier. (Am. Soc. Heat. & V. E.), April, 1918, p. 385-394.

Reasons for failure of heating systems. J. D. Hoffman. (Am. Soc. Heat. & V. E.), July, 1918, p. 633-642.

HOUSE DRAINAGE.

The relative corrosion of cast-iron, wrought-iron and steel pipe in house drainage systems. William Paul Gerhard. (Am. Soc. M. E.), Nov., 1918, p. 945-947, incl. 4 half-tones.

HUDSON RIVER, TROY, N. Y.—LOCKS. *See* LOCKS AND LOCK GATES.

INSTRUMENTS. *See* also TESTING METALS.

LIFT-BRIDGES. *See* BRIDGES.

LOCKS AND LOCK GATES.

Construction of concrete lock in Hudson River at Troy, N. Y., 1916, in charge of Col. W. M. Black, Corps of Engineers. M. J. McDonough. (Prof. M.), Sept.-Oct., 1918, p. 591-632, incl. half-tones, sections, diagrs., etc.

LOCKWOOD SYSTEM. *See* PRESERVATION OF TIMBER.

METALLURGY.

The ferro-alloys. J. W. Richards. (Gen. Elec. R.), Nov., 1918, p. 751-753.

MILITARY TRANSPORTATION—FRANCE.

La crise des transports en France. (Génie C.), Oct. 12, 1918, p. 293-294.

MOTOR CARS AND TRUCKS.
The motor truck as an aid to business profit. S. V. Norton. (Soc. Autom. E.), Nov., 1918, p. 309-316, incl. 4 figs. (half-tones, tables.)

MUNITIONS, FURNACES FOR.
Furnaces for munitions. (Sci. Am. S.), Nov. 2, 1918, p. 274.

MYSTIC RIVER BRIDGE. *See* BRIDGES.

NITRIC ACID MANUFACTURE. *See* CHEMISTRY, TECHNICAL.

NITROGEN FIXATION FURNACES. *See* ELECTRIC FURNACES.

OIL FEUL.
Oil fuel in the foundry in urgent cases. Capt. A. E. Plant. (P. Eng.), Oct 10, 1918, p. 176-177.

ORDNANCE—MANUFACTURE.
Development of gun manufacture. W. H. W. Skerrett. (Prof. M.), Sept.-Oct., 1918, p. 716-746 incl. 12 figs. (half-tones, tables, etc.)

PAVEMENTS. *See* also CONCRETE PAVEMENTS.

PIPES—LEAKS.
Practical method for detecting leaks in underground pipes. D. A. Heffer-man. (N. E. Wat. A.), Sept., 1918, p. 204-216.

POLLUTION OF STREAMS.
The polution of streams. Chesla C. Sherlock. (Eng. M. J.), Nov. 16, 1918, p. 861.

POWDERED COAL.
The use of coal in pulverized form. H. R. Collins. (Am. I. E. M.), April, 1918, p. 955-961.

RATS IN TRENCHES. *See* TRENCH SANITATION.

RECONSTRUCTION. *See* EUROPEAN WAR, 1914-18.—RECONSTRUCTION.

RESEARCH.
New Westinghouse research building. (Eng. M. J.), Nov. 16, 1918, p. 886.
Organization of industrial research. Arthur D. Little. (Eng. C. St. L.), Sept., 1918, p. 269-277.
Scientific and industrial researches. (Engi.), Sept. 27, 1918, p. 272-273.
The four phases of research. Henry M. Howe. (Eng. C. St. L.), Sept., 1918, p. 266-268.

ROADS.
Earth roads and air roads. Chas. H. Davies. (Sci. Am.), Nov. 2, 1918, p. 354.
The measure of a good road. Robert C. Barnett. (Eng. C.), Nov. 6, 1918, p. 438-440, incl. 3 figs, tables, scales, etc.)

ROADS, CONCRETE.
Finished method for concrete roads. E. Earl Glass. (Eng. C.), Nov. 6, 1918, p. 444, incl. 3 half-tones.

SALVAGE.
Le sauvetage des navires coulées. A. Poidloué. (Génie C.), Sept. 28, 1918, p. 241-244, incl. 6 half-tones.

SAND.
Progress report of committee on mechanical analysis of sand. (Ca. E.), Oct. 31, 1918, p. 381-390, incl. 2 tables.

SCLEROSCOPE. *See* TESTING METALS.

SCREW THREADS.
American-British gage bureau. (Soc. Autom. E.), Nov., 1918, p. 336.
National screw thread commission. (Soc. Autom. E.), Nov. 1918, p. 337-338.
Organization and proceedings of National screw thread commission. (Am. Soc. M. E.), Nov., 1918, p. 972-973.
S. A. E. Standard screws and bolts. (Soc. Autom. E.), Nov., 1918, p. 332-335, incl. 1 fig.
The measurement of thread gages. H. L. van Keuren. (Am. Soc. M. E.), Nov., 1918, p. 913-918, incl. 8 half-tones.

SEARCHLIGHTS.
Providing the searchlight with ears. (Sci. Am.), Nov. 9, 1918, p. 379. 160 words, 1 half-tone.

STAIRS AND STAIRWAYS.
Factory stairs and stairways. G. L. Arnold. (Am. Soc. M. E.), Nov., 1918, p. 928-932. 8 elevations.

STANDARDIZATION.
Dormant standards. (P. Eng.), Oct. 10, 1918, p. 169-170.

STEAM BOILERS.
Development of steam boiler baffles. A. A. Straub. (Power), Nov. 5, 1918, p. 656-659, incl. 10 figs. (sections, tables.)

STEEL PIPE. *See* also HOUSE DRAINAGE.

SUBMARINE CHASERS.
U-Boat chasers crossing the Atlantic. (Sci. Am.), Nov. 2, 1918, p. 353.

SUBMARINE DEFENSE.
Anti-U-Boat operations of the French navy. (Sci. Am.), Oct. 26, 1918, p. 333-344, incl. 5 half-tones.

TANKS. *See* TRACTORS, MILITARY.

TEMPLETS.
Templets, jigs and fixtures. J. Horner. (Eng.), Oct. 18, 1918, p. 422-424, incl. 3 figs. (elevation, sections, etc.)

TEREDO. *See* PRESERVATION OF TIMBER.

TESTING METALS.
Le scleroscope de Shore. (Bull. T. S. R.), Sept. 21, 1918, p. 179-180.
Quelques appareils pour l'essai rapide des metaux. (Bull. T. S. R.), Sept. 7, 1918, p. 170-172, incl. 3 figs.

TRACTORS, MILITARY.
Mechanical cavalry. (Sci. Am. S.), Nov. 16, 1918, p. 312-313, incl. 8 half-tones. See also frontispiece.

TRANSATLANTIC FLIGHT. *See* AVIATION.

TRENCH SANITATION.
The invasion of the trenches by rats. I. (Sci. Am. S.), Oct. 26, 1918, p. 259; II. Nov. 2, 1918, p. 278.

TROY, N. Y., HUDSON RIVER—LOCKS. *See* LOCKS AND LOCK GATES.

VANCOUVER—HARBOR. *See* HARBORS—CANADA.

WATERFALLS—FRANCE.
Comment s'est fait l'aménagement des chutes d'eau en France. J. T. Laspiere. (Génie C.), Oct. 5, 1918, p. 264-268, incl. 9 figs. (tables, maps, etc.); Oct. 12, 1918, p. 285-289.

WATER POWER.
Water powers of the empire. (Ca. E.), Oct. 31, 1918, p. 383-389; 391-392, incl. 2 tables.

WELDING.
Oxy-acetylene welding. G. B. Malone. (Prof. M.), Sept.-Oct., 1918, p. 751-761, incl. 2 half-tones.

ZEPPELIN BIPLANE. *See* AEROPLANES.

Articles of Engineering Interest.

Compiled with a view to including articles of civil and military engineering subjects of special interest to the readers of PROFESSIONAL MEMOIRS, Corps of Engineers and Engineer Department at Large. By Henry E. Haferkorn, Librarian, Engineer School.

NOTE—The following abbreviations are used, viz.:

Am. Mach.—*American Machinist*, New York.
Army N. G.—*Army and Navy Gazette*, London.
Autom. Ind.—*Automotive Industries*, New York.
Av.—*Aviation and Aeronautical Engineering*, New York.
Ca. E.—*Canadian Engineer, Toronto*, Canada.
Com. R.—*Commerce Reports*, Washington, D. C.
Com. Veh.—*Commercial Vehicle*, New York.
Concrete—*Concrete*, Detroit.
Dom. Eng.—*Domestic Engineering*, Chicago.
Elec. R.—*Electrical Review*, Chicago.
Génie C.—*Génie Civil*, Paris.
Geog. R.—*Geographical Review*, New York.
Illum. Eng.—*The Illuminating Engineer*, London.
Inf. J.—*Infantry Journal*, Washington, D. C.
Int. Marine Eng.—*International Marine Engineering*, New York.
J. U. S. Art.—*Journal of the U. S. Artillery*, Ft. Monroe, Va.
Metal Work.—*Metal Worker, Plumber, and Steam Fitter*, New York City.
La Metallurgie—*La Metallurgie*, Paris.
Motor A.—*Motor Age*, New York.
Munic Eng.—*Municipal and County Engineering*, Indianapolis.
Elec. W.—*Electrical World*, New York.
Eng.—*Engineering*, London.
Eng. C.—*Engineering and Contracting*, Chicago.
Eng. C. P.—*Engineers' Club* of Philadelphia. *Proceedings.*
Eng. C. W.—*Engineering and Cement World*, Chicago. Superceded by *Engineering World.*
Eng. and Min.—*Engineering and Mining Journal*, New York.
Eng. N.—*Engineering News*, New York. merged in *Engineering-News Record*, New York.
Eng. R.—*Engineering Record*, New York.
Eng. S. W. P.—*Engineers' Society of Western Pennsylvania*, Pittsburg. *Proceedings.*
Eng. W.—*Engineering World*, Chicago. Formerly *Engineering and Cement World*, Chicago.
Munic. J.—*Municipal Journal*, New York.
N. E. Wat. W. A.—*New England Water Works Association*, Boston.
Nat. S.—*National Service*, New York. Formerly *International Military Digest.*
La Nature— *La Nature*, Paris.
P. Eng.—*Practical Engineer*, London.
Power—*Power*, New York.
Prof. M.—*Professional Memoirs*, Washington Barracks, District of Columbia.
R. Eng. J.—*Royal Engineers Journal*, Chatham, Eng.
Riv. Art. G.—*Revista di Artiglieria e Genio*, Rome, Italy.
Roy U. S. I. I.—*Royal United Service Institution of India*, Simla. *Journal.*
Engi.—*The Engineer*, London.
Flying—*Flying*, New York.
Frank. I.—*The Franklin Institute*, Philadelphia. *Journal.*
Freight H.—*Freight Handling and Terminal Engineering*, New York.
R. U. S. I. L.—*Royal United Service Institution*,, London. *Journal.*
Sci. Am.—*Scientific American*, New York.
Sci. Am. S.—*Scientific American Supplement*, New York.
Soc. Autom. E.—*Society of Automotive Engineers*, New York.

(Prepared for PROFESSIONAL MEMOIRS, v. 11, No. 58, July-August, 1919.)

AERIAL NAVIGATION.

Airships versus airplane. Ladislas d'Orcy. (Sci. Am.), Feb. 1, 1919, p. 98-99 and 104.

AERIAL PHOTO-TOPOGRAPHY.

Topographic surveying by aerial photography. A. Brock, jr., and L. J. R. Holst. (Av). Feb. 15, 1919, p. 75-78, incl. 9 figs.

AERIAL PORTS. *See* AVIATION HARBORS.

AERIAL TRANSPORT.

Aerial transport. (Eng.), Dec. 13, 1918, p. 684-685.

Aerial transportation. E. J. David. (Flying), Mar., 1919, p. 172; 178, half-tone.

Civil aerial transport. (Engi.), Dec. 13, 1918, p. 511.

AERONAUTIC MAPPING.

The aero radio surveying and mapping.

J. N. Hammond, jr. (Flying), v. 8, no. 2 March, 1919, p. 160-161, incl. chart, diagrs.

Author explains his system of aerial radio survey which will be used by Capt. R. A. Bartlett in his expedition to explore the unknown regions of the earth in the Arctic Basin.

AERONAUTIC ORIENTATION.

Radio direction-finding apparatus. A. S. Blatterman. (Elec. W.), Mar. 8, 1919, p. 464-467. 11 figs.

AEROPLANE TELEPHONY.

Radio development in air service. Lieut. E. N. Doyle. (Eng. W.), Jan. 4, 1919, p. 27-29, incl. 6 sections.

Problems which the war has left still unsolved.—How shall satisfactory communication from one plane to another or from the ground to the air be attained? Necessity of policing the air factor in problem.

ARCH BRIDGES. *See* also STEEL BRIDGES.

ARMIES—ORGANIZATION.

The organization of the modern army. A. W. Chilton. (National Service) Feb., 1919, p. 69-73, incl. tables.

ARMY WAREHOUSES. *See* also under OCEAN TERMINALS.

AUTOMOBILES, MILITARY.

Motor transportation of infantry. C. B. Voorhees. (Inf. J.), Mar., 1919, p. 721-723.

AVIATION HARBORS.

Organization of aerial ports. G. Bastogi. (Av.), Feb. 1, 1919. p. 35.

BANK PROTECTION (RIVERS.)

Costal and shore protection. H. C. Campbell. (Eng. W.), Feb. 15, 1919, p. 11-17, incl. 11 half-tones, 7 figs.

Construction of breakwater and sea walls varies with location and conditions. —Revetment work is similar to concrete pavement.

BARGES.

How the New York canal concrete barge is being built. (Eng. N.), Feb. 1919, p. 268-274. Half-tones and sections, etc.

Side launching of concrete barges at the Aberthaw Yard. (Int. Marine Eng.) Feb., 1919, p. 104-105. 1 half-tone.

BIBLIOGRAPHY.

Aerial photography (Prof. M.), Nov.-Dec., 1918, p. 855-884.

BREAKWATERS.

Costal and shore protection. H. C. Campbell. (Eng. W.), Feb. 15, 1919. p. 11-17 incl. 11 half-tones. 7 figs.

Construction of breakwaters and sea walls varies with location and conditions. —Revetment work is similar to concrete pavement.

BROOKLYN, N. Y.—ARMY BASE TERMINALS.—*See* OCEAN TERMINALS.

CAMOUFLAGE.

The principle of camouflage—I. M. Luckiesh. (Sci. Am.), Jan. 25, 1919, incl. 3 half-tones; II. Feb. 8, 1919, p. 116; III. The visibility of airplanes. Feb. 22, 1919, p. 168; 181-182.

The art and concealment and deception as practiced on land.

Principles underlying ship camouflage. A. Bement. (Int. Marine Eng.), Feb., 1919, p. 90-92. 9 figs.

CAMP DRAINAGE. *See* CAMP SANITATION.

CAMP SANITATION.

Camp drainage and sanitation. W. H. Beswick. Transcript. (R. Eng. J.), Jan., 1919, p. 19-23.

CANAL BOATS. *See* BARGES.

CANALS—CANADA.

The Georgian Bay canal. J. J. Bell. (Engi.), Dec. 20, 1918, p. 527-528, 1 plan.

CEMENT—CONCRETE. *See* also under RESERVOIRS.

Blast furnace slag in concrete and reinforced concrete. J. E. Stead. (Eng. W.), Feb. 15, 1919, p. 36-38.

CEMENT GUN.

Engineering features of cement gun. B. C. Collier. (Eng. C. W.), Jan. 1, 1919, p. 31-35, incl. 3 half-tones, 1 section, 1 plan.

One of the most interesting mechanical devices that has been brought before the engineering world and one that gives promise of changing types and methods of construction.

COAST DEFENSE.

Notes on the use of the aeroplane in coast defense. J. H. Hammond, jr., (J. U. S. Art.), Sept.-Dec., 1919, p. 286-291.

COFFERDAMS. *See* also under LOCKS AND LOCK GATES.

CONCRETE CONSTRUCTION.

A new system of reinforced concrete construction. (Engi.), Dec. 27, 1918, incl 3 half-tones, 1 plan.

CONVEYORS.

Conveyors in relation to engineering works. W. W. Atherton. (Eng. W), Feb. 15, 1919. p. 27-30. 4 sections.

COST ACCOUNTING. *See* ENGINEERING—ESTIMATES AND COST.

CURVED OR HIGH-ANGLE FIRE. *See* EXTERIOR BALLISTICS.

DAMS. *See* also LOCKS AND LOCK GATES.

DEMOBILIZATION—*See* GT. BRITAIN—ARMY—DEMOBILIZATION.

DEMOLITIONS.

Demolitions under fire. T. E. L. (R. Eng. J.), Jan., 1919, p. 6-10.

DERRICKS.

Mammoth derricks build concrete outlet for Lockington Dam. (Eng. N.), Feb. 13, 1919, p. 326-327. 1 half-tone.

DIESEL ENGINE. *See* GAS AND OIL ENGINES.

DIRECTION-FINDING APPARATUS. *See* AERONAUTIC ORIENTATION.

EMBANKMENTS.

Wire-bag method of riprapping embankment. L. E. Foster. (Eng. W.), Feb. 15, 1919, p. 25-26. 1 fig.

EMBARKATION.

Embarkation a lecture delivered by Brig. General R. S. St. John. (Roy. U. S. I.), Jan., 1919, p. 101-135.

ENGINEERING—CONGRESS.

News of the week. (Eng. N.), Feb. 13, 1919, p. 348-349.

ENGINEERING—ESTIMATES AND COST.

Equipment and maintenance factors in cost accounting during transition period. L. W. Alwyn-Schmidt. (Am. Mach.,) Feb. 20, 1919, p. 366-368.

ENGINEERING—HISTORY.

Links in the history of engineering. R. Jenkins (Engi.), Dec. 20, 1918, p. 534-536, incl. 3 figs.

ENGINEERING—SOCIETIES.

American engineering standards committee (Power), March 4, 1919, p. 337.

EUROPEAN WAR, 1914-18—AMERCAN EXPEDITIONARY FORCE.

General Pershing's official story. (Inf. J.), Mar., 1919, p. 691-706.

Battles fought by American Armies in France from their organization to the fall of Sedan.

General Pershing's own account of the A. E. F. . . General John J. Pershing. Commander-in-Chief (National Service), Feb., 1919, p. 100-105.

EUROPEAN WAR, 1914-18.—ENGINEER SERVICE.

Work by R. E. units in the war (R. Eng. J.), Feb., 1919, p. 33-42.

EUROPEAN WAR, 1914-18.—PERSONAL NARRATIVES—AMERICAN.

The fourth year in France. F. K. Morris. (Eng. C. P.), Mar., 1919, p. 79-91. 6 half-tones. 2 figs.

Some things I saw and heard in England and France. H. L. Aldrich. (Int. Marine Eng.), Feb., 1919, p. 67-70, incl. 5 half-tones, figs, etc.

EUROPEAN WAR, 1914-18—RECONSTRUCTION.

The facts on the devastation and the present reconstruction efforts in France. G. B. Ford. (Eng. N.), Jan. 30, 1919, p. 218-227. 7 half-tones, 1 map.

The rebuilding of devasted France. John V. Schaefer. (Eng. C. W.), Jan. 15, 1919, p. 36-38.

Definite plan for the physical reconstruction of France and possibly of Europe.

EUROPEAN WAR, 1914-18—TONNAGE LOSSES.

British and world's merchant tonnage lost through enemy action and marine risks. (Eng.), Dec. 13, 1918, p. 677, incl. 4 tables.

EXTERIOR BALLISTICS.

Il tiro verticale. E. Cavalli, Maggiore generale. (Riv. Art. G.), Settembre, 1918, p. 115-164.

Contents.—Premessa.—1. L'altezza nel movimento ascendente.—2. La durata del movimento ascendente.—3. L'altezza nel movimento discendente.—4. Durata nel movimento discendente.

FIRE CONTROL—ARTILLERY.

Radio apparatus for artillery fire control. G. F. Gray and J. W. Reed. (Elec. W.), Mar. 1, 1919, p. 408-412. 6 figs.

FLOATING CRANES.

Floating cranes of 75-ton capacity. (Eng. C. W.), Jan. 15, 1919, p. 63-64, incl. 1 plan.

FLOATING DOCKS.

Building floating docks in Black Sea. (Eng. C. W.), Jan. 1, 1919, p. 25-26, incl. 1 plan.

Pontoons built separately, special methods of punching plates—Sidewalls erected after the floating of pontoons.

FLOODS AND FLOOD CONTROL.

Colorado River flood control by storage. E. C. La Rue. (Eng. N.), March 6, 1919, p. 456-461. 5 half-tones, 2 charts.

Reservoirs at available sites would so cut the flood at Yuma as to safeguard the Imperial Valley.—Water-power and irrigation opportunities.—A hundred more gaging stations needed.

FORTIFICATIONS.

Concealment in fieldworks. F. D. Napier-Clavering. (R. Eng. J.), Feb., 1919.

Old and new opinions about the value of permanent and fortified positions. (Prof. M.), Nov.-Dec., 1918, p. 789-819.

FORTIFICATIONS, PERMANENT.

The future of permanent fortification. H. E. G. Clayton. (R. Eng. J.), Feb., 1919, p. 43-46, 1 fold. map.

GEORGIAN BAY CANAL. *See* CANALS—CANADA.

GT. BRITAIN—ARMY—DEMOBILIZATION.

British demobilization plans. R. C. Clothier. (Inf. J.), Feb., 1919, p. 617-625.

GUN EMPLACEMENTS.

Notes on the field emplacement of a German large calibre gun. G. B. Pillsbury. (Prof. M.), Nov.-Dec., 1918, no. 54, p. 846-853. 3 figures, sections.

HARBORS—FRANCE.

L'exploitation des ports maritimes français pendant la guerre. (Génie C.), Jan. 25, 1919, p. 73-74.

Importance of French deep-water ports. (Com. R.), Dec. 31, 1918, p. 1220.

This is a translation of an article by M. Renaud, published in "l'Intransigeant" elucidating the importance of deep-water ports in relation to the expansion of commerce and communications. The author has made a special study of French ports.

HARBORS—INDIA.

India's seaports. (Freight H.), Jan., 1919, p. 31-32.

HARBORS—RUSSIA.

Siberian Ports north of Vladivostok. (Freight H.), Jan., 1919, p. 22-25.

HARBORS—STRAITS SETTLEMENTS.

Améliorations récentes du port de Singapour. (Génie C.), Jan. 25, 1919, p. 61-66. half-tones, sections, etc.

Singapour harbor and dock improvement. (Eng. W.), Feb. 1,1919, p. 31-34, incl. half-tones and sections.

HARBORS—U.S.

Harbor improvements at San Francisco. C. W. Geiger. (Int. Marine Eng.), Jan., 1919, p. 31-35, incl. 5 half-tones, 2 plans.

Extensive enlargement of piers.—Large bulkhead warehouses—Railroad connection with piers—Developments in Islais Creek section.

New York port's future a serious question. (Freight H.), Jan., 1919, p. 16-18.

The port of Seattle. W. A. Scott. (Eng. C. W.), Jan. 15, 1919, incl. 4 half-tones.

HARBORS—U. S.—PACIFIC.

Water front improvements in California. Charles W. Geiger. (Eng. C. W.), Jan. 1, 1919, p. 15-18, incl. 4 half-tones.

HAULAGE.

City of York, Pa., develops highway transport through study of goods available. K. H. Lansing. (Com. Veh.), Jan.. 15, 1919, p. 16-17, 1 map.

Large map of routes and list of truckers aid work.

HEATHCOTE SYSTEM. *See* CONCRETE CONSTRUCTION.

HIGH-ANGLE FIRE. *See* EXTERIOR BALLISTICS.

HOISTING MACHINERY. *See* DERRICKS.

HUDSON RIVER, TROY, N. Y. *See* LOCKS AND LOCK GATES.

HUDSON RIVER TUNNEL. *See* TUNNELS AND TUNNELING.

HYDROPHONE.

The Hydrophone for locating submarines. (Sci. Am.), Mar. 8, 1919, 3 figs.

INLAND NAVIGATION. *See* also WATER TRANSPORTATION.

Inland water transportation. C. Tompkins. (Freight H.), Jan., 1919, p. 21-22.

The relation of highways to railways and waterways. G. H. Pride. (Eng. C.), Mar. 5, 1919, p. 253.

INLAND NAVIGATION—FRANCE.
Le réseau navigable de la Saône. (Génie C.), Dec. 14, 1918, p. 466-468, incl. 1 map, 1 table.

INTRENCHMENTS.
Notes on experimental apparatus for setting out models of trenches. H. Church. (R. Eng. J.), Jan., 1919, p. 1-5, incl. figures, sections, etc.

ITALY—HARBORS.
Le pont d'Ostia Nuova, près de Rome et le chemin de fer d'Ostia à Rome. (Génie C.), 4. Jan., 1919, p. 12-13, 1 map, 1 plan.

KENTUCKY RIVER. *See* also INLAND NAVIGATION—U. S.

LIAISON.
Liaison. A. G. C. (J. U. S. Art.), Sept.-Dec., 1918. p. 291-296.

LOCKS AND LOCK GATES.
Government work on Hudson River. (Eng. C. W.), Jan. 15, 1919, p. 11-15, incl. 7 half-tones.
The new dam and lock on the Hudson river involved not merely the construction work at the new site, but also the removal of old works.
Sheet piling and forms used at Troy dam and locks. (Eng. W.), Feb. 1, 1919, p. 25-30. 7 half-tones.

MACHINE-GUNS.
Organization of machine-gun service. T. W. Brown. (Inf. J.), March, 1919, p. 742-746.

MAGDELENA RIVER, COLUMBIA. *See* WATER TRANSPORTATION.

MAP MAKING.
A combined map and panorama for orientation from lockout stations. E. Fritz. (Geog. R.), Dec., 1918, p. 501-503. 2 half-tones, 1 map
Topographic engineers assist in military mapping. R. B. Marshall. (Eng. N.), Jan. 30, 1919, p. 235-236. 2 half-tones.

MILITARY BRIDGES.
Launching an Inglis bridge. Capt. A. Taylor, R. E. (R. Eng. J.), Dec., 1918, p. 225-226, incl. 4 half-tones, 1 plan (fold).

MILITARY ENGINEERING—FIELD OPERATIONS.
The arcana of the Royal Engineers. H. M. Johnstone, (Army N. G.), Nov. 23, 1918. 1200 words.
See digest of this article in: National Service, Feb., 1919, p. 99.

MILITARY RAILROADS.
British railways under war conditions. (Engi.), Dec. 27, 1918, p. 556-557, 2 maps.
No. xiii.* The British expeditionary force at Southampton.

MISSISSIPPI RIVER. *See* also WATER TRANSPORTATION.
Revival of Mississippi River Traffic—II. M. Von Pagenhardt. (Int. Marine Eng.), March, 1919, p. 161-165, figs. 4-8.

MOTOR TRANSPORT. *See* AUTOMOBILES, MILITARY.

MOTOR TRANSPORT CORPS. *See* U. S. ARMY.

MOTOR TRUCK REPAIR.
Camp Holabird motor truck repair shops. (Soc. Autom. E.), Feb., 1919, p. 86-87.

NEW YORK CITY—HARBOR. *See* HARBORS—U. S.

OCEAN TERMINALS.
Brooklyn army base is largest port terminal. (Eng. N.), Feb. 13, 1919. p. 317-323. 2 half-tones, 6 figs.
The Brooklyn army supply base. H. Gardner. (Eng. W.), March 1, 1919. p. 11-16, 9 half-tones.
Freight movements at Marine terminals. H. McL. Harding. (Freight H.), Jan., 1919. p. 25-27.
Marine terminals and foreign commerce. H. McL. Harding. (Int. Marine Eng.), March, 1919, p. 149-151. 2 half-tones.
Quartermaster terminal required for war work. Major C. R. Glow. (N. E Wat. W. A.), Dec., 1918. p. 362-375, incl. 6 half-tones.

ORDNANCE.
Les canons de tranchée du système Stokes. (Génie C.), Jan. 25, 1919, p. 70-73, incl. half-tones, sections, etc.
Guns for the fighting front. (Sci. Am.), Jan. 18, 1919, p. 54-55, incl. 8 half-tones.
American heavy artillery designed and built for our armies in France.
Monster artillery. (R. Eng. J.), Jan., 1919, p. 26-30.
155-mm. Howitzer production. (Am. Mach.), Jan. 23, 1919, incl. 1 chart.
The 14-in. Naval railway batteries. C. L. McCrea. (Am. Mach.), Jan. 23, 1919, p. 141-150, incl. 10 half-tones, 2 plans.
With the close of the war more complete details are available regarding the design and construction of the Navy's expeditions of 14-inch guns on railway mounts that were sent to France to assist our army on the western front. . . .
Railway artillery. J. B. Dillard, U. S. A. (Mech. Eng., N. Y.), Jan., 1919. p. 44-49. Figures, sections, etc.
The Stokes gun and shell and their development. W. Stokes. (Prof. M.), Nov.-Dec., 1918, no. 54. p. 765-788. 24 figures, half-tones.

ORDNANCE—GUN MOUNTS.
Railway gun mounts. G. M. Barns. (Am. Mach.), Feb. 20, 1919. p. 329-335. 15 half-tones.

ORDNANCE, INSPECTION OF.
U. S. Army ordnance news. How ordnance is inspected. F. H. Colvin, (Am. Mach.), Feb. 6, 1919, p. 263-268.

ORIENTATION. *See* AERONAUTICS—ORIENTATION.

OSTIA NUOVA—HARBOR. *See* HARBORS—ITALY.

PANAMA CANAL.
Our canal-zone dry docks and repair shops. R. D. Gatewood. (Am. Mach.), Feb. 20, 1919. p. 336-340. 1 half-tone.

PARIS—CONGRESS OF ENGINEERING 1918-19. *See* ENGINEERING CONGRESSES.

PERSHING, JOHN J. *See* EUROPEAN WAR.

PHOTOGRAPHY.

Dyes in Photography. Dr. A. Seyewetz. (Sci. Am), Jan. 4, 1919. p. 6.

Their use in orthochromatic work and for non-halation plates.

Modern applications of photography. Alfred B. Hitchins, (Frank I.), Feb. 1919, p. 129-146. 11 half-tones, 2 sections.

Photographs on salted paper. L. Cartwright. (Sci. Am. S.), Feb. 8, 1919, p. 95-96.

PROJECTILES.

Curious projectiles. (Sci. Am.), Jan. 11, 1919, p. 28-29, incl. 6 figs., 1 plan, 5 sections.

Specimens of German and Austrian ingenuity.

PROMOTIONS—ARMIES.

Promotions in foreign armies. J. R. M. Taylor. (Inf. J.), March, 1919, p. 750-759.

RADIO AIR SERVICE. *See* AEROPLANE TELEPHONY.

RENAULT TANK. *See* TRACTORS, MILITARY.

REPAIR WORKSHOPS, MILITARY.

Workshop repair train in Flanders. (Engi.), Dec. 27, 1918, p. 550-551. 6 half-tones.

RESERVOIRS.

18,000,000 gallon reservoir at Winnipeg. (Engi.), Dec. 27, 1918, p. 545-548, incl. 8 half-tones, sections and plans.

RETAINING WALLS.

Reconstruction of a retaining wall of the Great Central Railway. (Engi.), Dec. 20, 1918, p. 536-537, incl. 3 figs.

RIVER TERMINALS.

Inland river terminals. H. McL. Harding. (Eng. C. W.), Jan. 1, 1919, p. 27-29, incl. 1 plate, 1 half-tone.

RIVER TRAFFIC. *See* WATER TRANSPORTATION.

ROADS.

Engineers must study road foundations. (Eng. W.), Feb. 15, 1919, p. 31-35.

Foundations for highways should be constructed with a view to bearing the greatest possible load under all conditions.—They should prove capable of withstanding the impact of a light vehicle in good weather and of sustaining the load of the heaviest truck when roads are bad.—Otherwise, the road will prove disappointing when the need is greatest.

Road corrugation. E. L. Leeming. (R. Eng. J.), Jan., 1919, p. 11-13.

Investigations in the structure of road surface. F. Wood, ibid., p. 13-16.

Notes on road construction and maintenance. I. B. Bower, ibid., p. 16-18.

SALVAGE.

Salvaging industrial wastes. W. R. Conover. (Gen. Elec. R.), Jan., 1919, p. 88-91.

Where nothing goes to waste. (Sci. Am.), Jan. 4, 1919, p. 6, incl. 5 half-tones.

Glimpses of the U. S. Army's salvage.

SAN FRANCISCO—HARBOR. *See* HARBORS—U. S.

SAONE RIVER—NAVIGATION. *See* INLAND NAVIGATION—FRANCE.

STEEL.

Les proportions économiques des ponts en arc en acier. (Génie C.), Dec. 14, 1918, incl. 1 table, 4 figs.

STEEL, STRUCTURAL.

New and little known methods of calculation of girders, beams and arches. J. S. Martin (Eng. S. W. P.), Dec., 1918. p. 579-639, incl. 22 diagrams, tables, etc.

STOKES GUN. *See* ORDNANCE.

SUBMARINE DEFENSE. *See* also HYDROPHONE.

SUBMARINES.

Un mystère dévoilé: les ''Q-Boats.'' V. Forbin. (LaNature), Jan. 11, 1919, p. 409-412. 4 half-tones.

The submarine situation. C. H. Cloudy. (Sci. Am.), March 1, 1919, p. 198-99. 4 half-tones.

The submarine with 12-inch guns a fact—and some other facts.

''TANKS.'' *See* TRACTORS, MILITARY.

TERMINAL SHED.

Marine terminal shed. H. McL. Harding. (Eng. C. W.), Jan. 15, 1919, p. 47-48, incl. 1 half-tone.

The advantage of the 1-story shed over the 2-story are many in both cost and speed of operation.

TOWBOATS.

Twin-screw steam towboat—The Peace. (Int. Marine Eng.), Feb., 1919. p. 93. 1 half-tone.

TRACTORS, MILITARY.

Chars d'assaut et péniches. R. Villers. (LaNature), Jan. 25, 1919, incl. 4 half-tones.

First description of the Ford ''Baby'' tank. (Autom. Ind.), Jan. 9, 1919, p. 43-46, incl. 3 half-tones, 3 sectons.

A two-man fighting machine having a duplicate Ford automobile power plant. —Radiator mounted at rear in most protected position.—Worm drive.—Armor plate body forms chassis frame.

The French baby Renault tank. W. F. Bradley. (Autom. Ind.), Feb. 27, 1919, p. 465-470. 5 half-tones, 6 figs.

Weight 6½ tons complete with machine gun.—Has a maximum speed of 4.8 M. P. H.—Can climb a gradient of 119 per cent.—Is driven by a small four-cylinder engine and can be handled efficiently by two men.

The mark viii land cruiser. J. E. Schipper. (Autom. Ind.), Jan. 2, 1919, p. 7.-10. Mark VIII tank a 35-tonner. (Motor A.) Jan. 2, 1919, p. 18-21, incl. 9 half-tones.

Liberty engine used in huge model that carries eleven men.

TRANSPORTATION. *See* also under INLAND NAVIGATION.

TRANSPORTATION-GT. BRITAIN.

Transportation in the United Kingdom. Consul H. Lee Washington, Liverpool, Dec. 6, 1918. (Com. R.), Jan. 31, 1919, p. 483-484.

TRENCH WARFARE.

A hitch in the trenches. E. E. Lewis. (Inf. J.), Mar., 1919. p. 707-718.

TROY, N. Y.—LOCKS AND DAMS. *See* LOCKS AND LOCK GATES.

TUNNELS AND TUNNELING.

The proposed vehicular tunnel under the Hudson River. (Sci. Am.), Mar. 8, 1919. p. 222-223, 1 half-tone, cross-sections.

Vehicular tunnels under the Hudson River. M. Schreiber. (Frank. I.), March, 1919. p. 273-288. 1 map, plans, cross-sections, etc.

U. S.—ARMY—MOTOR TRANSPORT CORPS.

Engineering Division of the Motor Transport Corps. (Soc. Autom. E.), Jan., 1919, p. 5-8. 1 section; Feb., 1919. p. 77-85. 3 tables, 1 diagram.

VERTICAL FIRING. *See* EXTERIOR BALLISTICS.

WATER—SUPPLY.

The Chlorination of water supplies. W. J. Orchard. (Eng. W.), Feb. 1, 1919, p. 17-19. 1 half-tone, 1 section.

WATER—SUPPLY, MILITARY.

Water for an army. (Sci. Am. S.), Jan. 18, 1919, p. 36, incl. 6 half-tones.

Successful hygienic work of great importance.

WATER TERMINALS.

Analysis of freight movements at terminals. H. McL. Harding. (Int. Marine Eng.), Feb., 1919, p. 88-89. 1 half-tone, 1 fig.

WATER TRANSPORTATION.

Revival of Mississippi river traffic—I. M. Von Pagenhardt. (Int. Marine Eng.), Feb., 1919, p. 80-82. half-tones, figs.

Transportation on the Magdelena River, Columbia. H. W. Wright. (Sci. Am. S.), Feb. 8, 1919. p. 88-89. 6 half-tones.

WELDING.

Acetylene welding and war work. A. F. Wickenden. (P. Eng.), Jan. 16, 1919, p. 27-28. 3 figs., (sections).

Modern welding and cutting. E. Viall. (Am. Mach.), Jan. 6, 1919, p. 243-248. 2 tables, 6 figs, sections, etc. Feb. 13, 1919, p. 283-291. 25 figures, half-tones, sections. Feb. 20, 1919, p. 341-346 incl. figs. no. 27-36; Feb. 27, 1919, p. 389-94. figs. 37-52.

III—Thermit welding crankshafts, mill pinions, etc.

Previous installments have given detailed directions for making both plastic and fusion welds. This article gives specific directions for applying the principles of fusion welding to the repair of crankshafts and replacing teeth in large pinions, rudder stocks and the like.

Oxy-Acetylene Welding and Cutting. (Eng. M. J.), Feb. 8, 1919. p. 268-269.

WHARVES.

Wharf equipment. Roy S. Mac Elevee. (Prof. M.), Nov.-Dec., 1918. no. 54, pages 820-840, incl. half-tones, sections, etc.

Articles of Engineering Interest.

Compiled with a view to including articles of civil and military engineering subjects of special interest to the readers of PROFESSIONAL MEMOIRS, Corps of Engineers and Engineer Department at Large. By Henry E. Haferkorn, Librarian, Engineer School.

Note.—The following Abbreviations have been used.

Am. Mach.—American Machinist, New York.
Autom. Ind.—Automotive Industries, New York.
Ca. E.—Canadian Engineer, Toronto, Canada.
Com. Veh.—Commercial Vehicle, New York.
Elec. W.—Electrical World, New York.
Eng.—Engineering, London.
Engi.—The Engineer, London.
Eng. M. J.—Engineering and Mining Journal, N. Y.
Eng. N.—Engineering News-Record, New York.
Eng. W.—Engineering World, formerly Engineering and Cement World and Cement Era, Chicago.
Flying—Flying, New York.
Génie C.—Le Génie Civil, Paris.
Inf. J.—Infantry Journal, Washington, D. C.
Mech. Eng., N. Y.—Mechanical Engineering. Journal of the Am. Society of Mech. Engineers, New York.
Mem. I. E.—Memorial de Ingenieros del Ejército, Madrid.
La Nature—La Nature, Paris.
Naut. G.—Nautical Gazette, N. Y.
Power.—Power, New York.
Sci. Am.—Scientific American, N. Y.
Sci. Am. S.—Scientific American Supplement, New York.
S. I. E. N.—Société d'Encouragement pour l'Industrie Nationale, Paris.
Tech. M.—La Technique Moderne, Paris.

ABUTMENTS. See BRIDGES—ABUTMENTS.

ACETYLENE.

Les principaux composés organiques dérivés de l'acétylène. D. Florentin. (Génie C.), 15 mars, p. 209-212; 22 mars, 1919, p. 235-236, incl. formulas, table.

Synthèses industrielles de l'alcool, de l'acide, de l'anhydride et des éthers acéthique, du butadiène, etc.

AERIAL PHOTOGRAPHY.

Broad field for commercial aerial photography. Capt. A. Kinney, jr., A. S. A. (Flying), v. viii, no. 3. April, 1919, p. 250-255, incl. 9 half-tones.

Contents. Photographic mapping, p. 251-253. Importance of aerial photography in forestry, p. 253.

AERIAL TRANSPORT.

Aerial transportation. Evan J. David. (Flying), April, 1919, p. 262-276, incl. 3 half-tones.

The inauguration of safe aerial transportation. Harold F. Blanchard. (Autom. Ind.), April 17, 1919, p. 845-849, incl. half-tones.

Helium gas for balloon inflation and the likely results of discovery of means for producing it cheaply in quantity.

(Prepared for PROFESSIONAL MEMOIRS, v. 11, No. 59, Sept.-Oct., 1919.)

Contents. Helium is non-inflammable. Helium found in sun spectrum. The landing problem. Wings cause of trouble. Helium-filled dirigibles logical for commercial use.

AMMUNITION.

British munitions. C. H. Claudy. (Sci. Am.), April 12, 1919, p. 375, incl. chart, 2 half-tones.

A glimpse at a picture too big for a single canvas.

ANTI-AIRCRAFT GUN SIGHTS.

Making gun sights for anti-aircraft guns. Fred. H. Colvin. (Am. Mach.), April 10, 1919, p. 681-684, incl. 10 half-tones.

"The special fixtures used in connection with the main parts of these gun sights are full of suggestions for other purposes." . . .

ARMY WAREHOUSES.

Electrical service at great seaboard terminal. (Elec. W.), April 19, 1919, p. 784-787, incl. half-tones, section.

Boston army supply base, costing $28,000,000, is equipped for maximum efficiency in handling and storing either war or peace supplies.

Electrical agencies include elevators, cranes and industrial tractors and trailers.

Wood construction feature of Charleston port terminal. Hunley Abbott. (Eng. N.), April 10, 1919, p. 702-706, incl. 2 half-tones, plan, sections, etc.

. . . Design at army supply base largely dictated by war emergency, but docks and warehouses illustrate modern use for such work.

ASPHYXIATING GAS. See GASES, ASPHYXIATING AND POISONOUS.

AUSTIN DAM, TEXAS. See DAMS.

BARGES. See also CONCRETE SHIPS—WATER TERMINALS.

BORING MACHINES. See MACHINE TOOLS.

BOSTON ARMY SUPPLY BASE. See ARMY WAREHOUSES.

BRASS. See also CORROSION AND ANTI-CORROSIVES.

BRASS MELTING.

Melting brass in a rocking electric furnace. (Eng.), March 14, 1919, p. 329-332. incl. half-tones, diagrs., sections. Table i.

BRIDGES, CONCRETE.

Canada's longest reinforced concrete trusses. (Ca. E.) April 3, 1919, p. 345-348, incl. half-tones, diagrs., sections.

These are the two bridges that carry the Toronto-Hamilton highway across the Etobicoke River and Bronte Creek, each 119 feet, 1½ inches, clear span, with 20-foot roadway and 16-foot overhead clearance, arches rise 26 feet above floor level.

BRIDGES—ABUTMENTS.

Standard bridge abutments on canal projects. D. C. Willett. (Eng. N.), April 17, 1919, p. 777-778, incl. half-tones, sections, etc.

Two types of abutments, reinforced concrete and timber pile, are used on Rio Grande irrigation development.

CAMS.

Cam design and construction. F. DeR. Furman. (Am. Mach.), April 10, 1919, p. 685-689, incl. charts, diagrs.

ii. Formulae and factors.

April 24, 1919, p. 779-784, incl. diagrs. iii. Empirical and technical methods.

CEMENT-CONCRETE.

How to design concrete mixtures. (Eng. N.), April 17, 1919, p. 758-763, incl. diagrs.

Proper proportions can be determined for different kinds of material. New theories regarding aggregate grading advanced by D. A. Abram as result of tests.

Solubility of Portland cement and its relation to theories of hydration. J. C. Witt and F. D. Reyes. (Eng. W.), April 1, 1919, p. 39-41, incl. tables i-vii.

CENTRIFUGAL MACHINES.

Continuous centrifugal separation machines. (Eng.), March 14, 1919, p. 354-355, incl. illus., sections, etc.

CHARLESTON, S. C.—ARMY SUPPLY BASE. See **ARMY WAREHOUSES.**

CHEMICAL WARFARE SERVICE. See **GASES, ASPHYXIATING AND POISONOUS.**

COFFER-DAMS.

Notes on the design of a single-wall coffer-dam. F. R. Sweeny. (Eng. N.), April 10, 1919, p. 708-711, incl. 2 diagrs, sections, table.

Size and location of timber wales and braces and size of timber and steel sheeting developed from both theoretic and economic considerations.

CONCRETE. See **CEMENT-CONCRETE.** See also **SUBAQUEOUS CONCRETE.**

CONCRETE BARGES. See **CONCRETE SHIPS.**

CONCRETE ROADS. See **ROADS, CONCRETE.**

CONCRETE SHIPS.

British concrete shipyards. W. Noble Twelvetrees. (Eng.), March 14, 1919. p. 334-338, incl. illus., sections, etc. Fold plate xix.

CORROSION AND ANTI-CORROSIVES.

Corrosion of brass in sea water. Paul T. Bruhl. (Sci. Am. S.), April 5, 1919, p. 211.

Moyens de protection employés par les Allemands contre la rouille de leur matériel de guerre en acier. A. J. (Génie C.), 15 mars, 1919, p. 217-218.

DAMS.

Drift on the Colorado River held back by Austin Dam. T. U. Taylor. (Eng. N.), April 10, 1919, p. 724-725, incl. 1 half-tone.

Passes over the rounded top of old dam, but is caught by the present structures. All sorts and sizes of débris.

Record height concrete multiple-arch dam completed. (Eng. N.), April 10, 1919, p. 720-721, incl. 2 half-tones, plan, sections, etc.

Dam forming Lake Hodges in irrigation district near San Diego is 136 feet from crest to low point in valley.

DIESEL ENGINE.

Diesel engines and the merchant marine. Review of developments on the Pacific Coast. (Mech. Eng., N. Y.), April, 1919, p. 377-378.

Contents. Diesel engines on the Pacific Coast. Bruce Lloyd. Performance of the "Libby Maine". Geo. A. Dow.

Le moteur Diesel de moyenne puissance. P. Chabel. (Tech M.), Jan., 1919, p. 9-12, incl. 2 half-tones, 1 section, tables. Fév., 1919, p. 77-83, incl. 2 half-tones, sections, tables.

[illegible]

DRAW BRIDGES. See also under **FERRIES.**

DRILLING MACHINES. See **MACHINE TOOLS.**

ELECTRIC FURNACES. See **BRASS MELTING.**

ELECTRIC WELDING.

Electric welding. (Eng.), March 14, 1919, p. 350-351.

Abstract of three papers read before the Institution of Civil Engineers, March 11, 1919.

Contents. Electric welding developments in Great Britain and the U. S. J. Caldwell and H. B. Sayers. Experiments on the application of electric welding to large structures. W. St. Abell. The application of electric welding in ship construction and repairs. J. J. R. Smith.

Electric welding. J. H. Patterson. (Eng.), Feb. 28, 1919, p. 285-288, incl. half-tones, diagrs.

Electric welding and welding appliances. ii. (Engi.), Feb. 21, 1919, p. 172-173, incl. 7 figs. (sections, etc.): The Benardos Carbon arc process; iii. (Engi.), Feb. 28, 1919, p. 197-198. incl. diagrs,; iv. (Engi.), March 7, 1919, p. 220-222, incl. diagrs.; v. The Pontelec methods and machines. (Engi.), March 14, 1919, p. 241-243, incl. 7 half-tones.

Electric welding in the construction of steel vessels. (Eng.), Feb. 21, 1919, p. 254-256, incl. sections, etc.

Electric welding problems. Editorial. (Engi.), Feb. 28, 1919, p. 203-204.

Electric welding system. (Naut. G.), April 5, 1919, p. 237.

Its application to ship construction and repair work.

Welding in concrete shipyards. (Naut. G.), April 5, 1919, p. 237.

ENGINEERING—RESEARCH. See also **RESEARCH, INDUSTRIAL.**

Engineering research. (Mech. Eng.. N. Y.), Feb., 1919, p. 186-187; March, 1919, p. 294-295; April, 1919, p. 410-411, incl. 1 table, sections.

A department conducted by the Research Committee of the A. S. M. E., Arthur M. Greene, jr., chairman.

ENGINEERING—SOCIETIES.

Institution Mechanical Engineers. (Engi.), Feb. 2, 1919. p. 193-194.

Brief report of the annual meeting held Feb. 21, 1919.

There were read four papers on welding by Messrs. Heaton, Cave, Davies, and Hazeldine. Also notes by F. G. Martlew, on glasses and shield worn to protect welders from the glare of the arc or blowpipe.

The Institution of Mechanical Engineers. (Eng.), Feb. 28, 1919, p. 279-283.

Report of the annual meeting of the society on Feb. 21, 1919, incl. brief review of papers read.

ENGINEERING—STUDY AND TEACHING.

University training for engineers. (Elec. W.), April 5, 1919. p. 683-684.

A broader outlook, a fair knowledge of economics and government and human sympathies are necessary if the engineer is to be equipped properly for his work.

ENGINEERS, ORGANIZATION OF.

Engineering civic federation. W. L. Saunders. (Eng. N.), April 17, 1919, p. 756-757, incl. chart.

Proposed organization of engineering societies based upon one political system of representation.

Professional organization in England. (Eng. N.), April 10, 1919, p. 712-716.

Abstract of an analysis by Sidney and Beatrice Webb of the motives, methods and results of such organization, including that of Engineers.

EUROPEAN WAR, 1914-18.—ENGINEER SERVICE.

Engineering achievements of the army. (Mech. Eng., N. Y.), April, 1919, p. 372-374, incl. 5 half-tones.

Illustrations: 1. Portable foot bridge. 2. 60-inch portable searchlight on truck ready for transportation. 3. Long-horn listening device for locating enemy aircraft. 4. American paraboloid. A development of the long-horn set. 5. Phonotelemeter. American sound-ranging set for locating enemy batteries.

EUROPEAN WAR, 1914-18.—RECONSTRUCTION.

The reconstruction of Belgium industries. i. (Engi.), Feb. 28, 1919, p. 204-205; ii. March 7, 1919, p. 216-217; iii. March 14, 1919, p. 243-244.

EXPLOSIVES.

Liquid oxygen explosives. (Eng. M. J.), April 12, 1919. p. 657.

Abstract of an article published in the January issue of "Compressed Air Magazine".

FALMOUTH HARBOR. See HARBORS—GREAT BRITAIN.

FERRIES. See also WATER TERMINALS.

A Canadian train ferry. (Engi.), Feb. 21, 1919, p. 184, incl. sectional elevation.

Bac-transbordeur et pont tournant pour la traversée du canal maritime de Suez à Kantara. Jean Raimondi. (Génie C.), 15 mars, 1919, p. 201-209, incl. 3 figs. (half-tones, plan, sections, etc. Fold. plate iii.)

The Southampton train ferry. (Eng.), Jan. 24, 1919, p. 119-120, fold. plates vii, viii; Feb. 21, 1919, p. 238-241, incl. plan. sections, etc., fold. plates xii, xiii.

FILTERS AND FILTRATION.

Dundas has new filter plant on gravity supply. E. H. Darling. (Ca. E.), April 17, 1919, p. 379-382, incl. half-tones, map, sections.

Expenditure of only $30,000 provides progressive Ontario manufacturing town with modern filtration plant of 700,000 imperial gallons daily capacity. Concrete dam forms conservation reservoir and provides ample head for the 1½-mile pipe line to filtration plant.

FLOODS AND FLOOD CONTROL.

Flood control work in Washington. W. A. Scott. (Eng. W.), April 1, 1919, p. 23-28, incl. 12 half-tones.

The Inter-County River improvement, undertaken coordinately by the counties of King and Pierce, in the state of Washington, about 5 years ago, has progressed since then in accordance with the original plan, and by the end of 1919 practically the entire project will have been completed. The funds made available for the work amounted to $250,000 per year for 6 consecutive years, a total of $1,500,000.

FORTIFICATION, FIELD.

Modalidades novissimas de la fortificación de campaña. Son aceptables o no las ultimas ideas? Coronel de Ingenieros D. Juan Aviles. (Mem I. E.), Jan., 1919, p. 1-10.

FUEL. See also **PEAT.**

A new composite fuel. (Eng. M. J.), April 19, 1919, p. 691-692.

GAS AND OIL ENGINES. See also **DIESEL ENGINE.**

GAS MASKS. See **RESPIRATORS.**

GASES, ASPHYXIATING AND POISONOUS. See also **RESPIRATORS.**

United States chemical warfare service. ii. (Sci. Am.), April 12, 1919, p. 372-373, incl. half-tones.

The great plant at Edgewood Arsenal with a capacity of 200 tons per day.

GEARING, TOOTHED.

The manufacture and design of toothed gearing. Jos. Chilton. (Eng.), Feb. 21, 1919, p. 235-237, incl. diagrs.

GLASS, WELDING OF. See **WELDING.**

GLUE.

Properties and preparation of glues. (Mech. Eng., N. Y.), April, 1919, p. 382-384, incl. 3 figs.

Data on the properties, preparation, classification, grading and testing of glues, strength of glued joints, etc. Based on experimental work of Bureau of Aircraft Production.

HARBORS—FRANCE.

Les nouveaux agrandissements du port de Marseille et la creation d'un port à minerais. Aug. Pawlowski. (La Nature), 22 mars, 1919, p. 295-298, incl. 3 illus.

HARBORS—GREAT BRITAIN.

A new British port. Eric A. Dime. (Sci. Am.), April 12, 1919, p. 368, incl. 1 map.

Proposed dock in Falmouth Harbor that could accommodate 1,000-foot-liners.

HATFIELD 18-INCH ARMOUR-PIERCING SHELLS. See **PROJECTILES.**

HAULAGE.

Long-distance motor-truck haulage costs in Ohio. (Eng. N.), April 10, 1919, p. 717.

Routes between Akron, Youngstown and Cleveland investigated. Present rates too low. Operate for 52 cents per truck mile.

Ship-by-truck movement invades south to prove great benefits of highway transport. (Com. Veh.), April 15, 1919, p. 19-21, incl. half-tones, map, form.

Macon, Georgia, stages big demonstration in which four fleets of trucks deliver 100 tons of goods to nearby cities within 50-mile radius.

HOUSE DRAINAGE.

Cast-iron, wrought-iron and steel pipe for house drainage purposes. Paul Gerhard. (Eng. W.), April 1, 1919, p. 47-50, incl. 8 half-tones.

HYDRAULIC ENGINEERING.

Recherches sur la formation des sinuosités des cours d'eau. Colonel Hoc. (Génie C.), 15 mars, 1919, p. 212-215, incl. plan. maps, etc.; 22 mars 1919, p. 233-234, incl. diagrs.

HYDRAULICS.

New methods for the solution of backwater problems. H. R. Leach. (Eng. N.), April 17, 1919, p. 768-770, incl. diagrs, etc.

Use of diagrams with only one major variable reduces computations and leads to more accurate results.

The flow of water in large pipes and tunnels. (Eng.), Feb. 28, 1919, p. 288.

i. The flow of water in pipes and pressure tunnels, by Fred. John Mallett. ii. The discharge of large cast-iron pipe-lines in relation to their age, Alf. Atkinson Barnes.

Abstract of two papers read before the Institution of Civil Engineers, Feb. 25, 1919.

The measurement of fluid velocity and pressure. J. R. Pannell. (Eng.), Feb. 28, 1919, p. 261-263, incl. half-tones, sections, etc., March 7, 1919, p. 295-297, incl. illus., diagrs., etc.; March 14, 1919, p. 333-334, illus., sections, etc. To be continued.

HYDROPLANES.

The Phoenix Cork flying boat. (Engi.), Feb. 28, 1919, p. 194-196, incl. half-tones, sections, etc.

INTERNAL COMBUSTION ENGINES. See GAS AND OIL ENGINES. See also DIESEL ENGINE.

JIGS.

Templets, jigs and fixtures. xxi. Jos. Horner. (Eng.), March 7, 1919, p. 298-302, incl. illus., p. 312. Fold. plate xviii.

LAKE HODGES DAM. See DAMS.

LAND DRAINAGE. See also RIVER IMPROVEMENTS.

LIFT-BRIDGES.

Mechanical features of vertical-lift bridge. Dr. J. A. L. Waddell. (Mech. Eng., N. Y.), April, 1919, p. 379-381, incl. 4 half-tones.

Veteran bridge engineer's comments on Mr. Van Cleve's annual meeting paper, together with details of a recently constructed 260-foot double-track lift span.

MACHINE TOOLS.

Horizontal duplex boring, drilling and tapping machine. (Eng.), Feb. 21, 1919, p. 241, incl. plan, sections, etc., half-tones, p. 244.

Machine tools. Sir Alfred Herbert. (Eng.), March 14, 1919, p. 355-358.

Paper read before the North-East Coast Institution of Engineer and Shipbuilders, March 11, 1919.

New opportunities for machine-tool builders. L. W. Alwyn-Schmidt. (Am. Mach.), April 17, 1919, p. 751-752.

Putting the machine tool industry where it belongs. Fred H. Colvin. (Am. Mach.), April 17, 1919, p. 762-764.

The machine tool industry and the war. (Engi.), March 14, 1919, p. 254-255.

From a paper entitled: ''Machine tools by Sir Alfred Herbert, read before the North-East Coast Institution of Engineers and Shipbuilders, at New Castle-on-Tyne, March 11, 1919.

MARSEILLE—HARBOR. See HARBORS—FRANCE.

MECHANICAL STOKERS.

The Erith-Riley mechanical stoker. (Eng.), Feb. 28, 1919, p. 268, half-tones, sections, etc.

MERCHANT VESSELS. See also SHIPBUILDING.

MILITARY INSIGNIA.

Shoulder insignia of combat divisions. (Inf. J.). April, 1919, p. 832-839, incl. illus.

MILITARY RAILROADS.

Dwarf railways of the front line trenches. James E. Sellers. (Eng. N.), April 17, 1919, p. 774-775. incl. 1 half-tone.

The Soixante- or 60-centimeter-gage tracks used for many purposes. Connect with broad-gage railroads in battle areas.

MOTOR CARS AND MOTOR TRUCKS. See also HAULAGE.

MOTOR TRUCKS. See MOTOR CARS AND TRUCKS. See also HAULAGE.

NILE RIVER.

The Nile projects committee. (Engi.), March 7, 1919, p. 224.

The committee was appointed by the Sec'y. of State for foreign affairs to consider certain charges made by Lt. Col. M. R. Kennedy, and Sir W. Willcocks, in connection with certain Egyptian and Sudan irrigation projects . . .

OCEAN TERMINALS. See also ARMY WAREHOUSES.

ORDNANCE.

America's great effort in ordnance. i. (Sci. Am.), April 5, 1919, p. 338-339, half-tones, charts.

Supplying out two million men in France with artillery, machine guns and rifles.

Heavy field piece with mobile mount. Ensign C. L. McCrea, U. S. N., R. F. (Mech. Eng.), N. Y.), April, 1919. p. 375-376, incl. half-tone.

Illustration: 1. High-power 7-inch gun with caterpillar mounting.

PEAT.

The utilization of peat for power generation. John B. C. Kershaw. i. (Engi.), March 14, 1919, p. 239-240, incl. 2 half-tones, 2 maps.

PORTLAND CEMENT. See CEMENT-CONCRETE.

PROJECTILES. 4

18.-in. High-velocity armour piercing shells. (Engi.), March 7, 1919, p. 231, incl. 2 half-tones.

PUBLIC WORKS—U. S.

How should the federal department of public works be organized? Chas. Whiting Baker, (Eng. N.), April 10, 1919, p. 722-724.

Need for clear determination of what bureaus should be included, and how personnel should be protected and built up.

Public works department would spend over $125,000,000 annually. (Eng. N.), April 17, 1919, p. 757. 160 words, 1 table.

RADIO-TELEPHONY. See TELEPHONY, WIRELESS. See also AEROPLANE TELEPHONY.

RADIUM.

Radium and radio-activity. ii. Chas. H. Viol. (Sci. Am. S.), April 5, 1919, p. 214-215, incl. formulas.

A consideration of some of the physical and chemical aspects. Continued from Sci. Am. S. March 29, 1919.

RAILROADS—CARS.

Reinforced concrete gondola cars. (Eng. W.), April 1, 1919, p. 45-46, incl. 2 half-tones.

Illustrations: The concrete car complete. Interior of car, showing reinforcing.

RAILROAD ENGINEERING.

Dispositifs pour le raccourcissement des traversées-jonctions. A. Goupil. (Génie C.), 15 mars, 1919, p. 215-217, incl. 14 figs. (plan, diagrs., etc.)

RAILROADS—SIGNALING.

An improvement in railway signaling. (Engi.), March 14, 1919, p. 262. incl. 3 half-tones.

RAILROADS—TERMINALS.

The Chicago railway terminals. E. J. Noonan. (Eng. W.), April 1, 1919, p. 29-35, incl. 4 figs. (plans).

RESEARCH, ENGINEERING. See ENGINEERING—RESEARCH.

RESEARCH, INDUSTRIAL. See also ENGINEERING—RESEARCH.

The government scheme for industrial research. (Eng.), March 7, 1919, p. 317-318.

At end of article: "Dept. of Scientific and Industrial Research, 15, Great George-street, Westminster, S. W. 1."

The government scheme for industrial research. (Engi.), March 7, 1919, p. 237.

State aid for industrial research. Notes. (Eng.), March 7, 1919, p. 316.

RESEARCH, SCIENTIFIC. See also RESEARCH, INDUSTRIAL.

The department of scientific and industrial research. (Engi.), Feb. 21, 1919, p. 184.

Short review of a paper by Sir Frank Heatth, Sec'y. of the department, read before the Royal Society of Arts, on Feb. 12, 1919, on the history and development of that body.

RESPIRATORS.

Army gas masks in sulphur-dioxide atmospheres. A. C. Fieldner and S. H. Katz. (Eng. M. J.), April 19, 1919, p. 693-694, incl. half-tones, sections.

Illustrations. 1. U. S. Army gas mask, mouthpiece type. 3. Tissot-type gas mask. 2. Sectional diagrams of U. S. Army gas mask and canister.

Industrial use and limitations of respirators, gas masks and oxygen breathing apparatus. (Sci. Am. S.), April 19, 1919, p. 254.

From Chemical and Metallurgical Engineering.

RIVER IMPROVEMENT—GREAT BRITIAN.

Land drainage in Cambridgeshire. (Engi.), Feb. 21, 1919, p. 174-176, incl. map, half-tones, plan, sections.

RIVERS—REGULATION.

New river-straightening movement at Cleveland. (Eng. N.), April 17, 1919, p. 763-764, incl. plan.

Conservancy district proposed. Choice between central and west channels affected by union station scheme.

ROADS, CONCRETE.

A mechanical finisher for concrete roads. (Sci. Am.), April 12, 1919, p. 377, incl. 2 half-tones.

The case of the concrete road. Editorial. (Eng.), Feb. 21, 1919, p. 245-246.

ROAD ROLLERS.

A new road scarifier. (Engi.), March 14, 1919, p. 254, incl. 3 half-tones, 2 sections.

ROAD SCARIFIERS. See ROAD ROLLERS.

ROLLING MILLS.

The government rolling mill, Southampton ii. (Engi), Feb. 28, 1919, p. 191-193, incl. 6 half-tones, plan; ii. March 7, 1919, p. 217-219. incl. 2 half-tones, fold. plate.

RUST. See CORROSION and ANTI-CORROSIVES.

SAN DIEGUITO RIVER, DAM ON. See DAMS.

SCREW MACHINES.

Screwing machines for bent tubes. (Eng.), Feb. 28, 1919, p. 285, incl. half-tone.

SCREW THREADS.

Cutting threads of unusual pitch. Wm. A. Frank, (Am. Mach.), April 17, 1919, p. 747.

SEA MINES..

Sweeping for mines. (Eng.), Feb. 28, 1919, p. 273, incl. half-tone, diagrs.

SHELLS. See PROJECTILES.

SHIPBUILDING.

The world's shipbuilding. (Eng.), Feb. 28, 1919, p. 284. incl. 2 tables.

Table i. Number and tonnage of merchant vessels launched in the United Kingdom 1916-18. ii. Number and tonnage of merchant vessels of 100 tons gross and upwards launched in the various countries of the world during 1892-1918.

SIGHTS FOR FIRE-ARMS. See also ANTI-AIRCRAFT GUN SIGHTS.

SNOW REMOVAL.

Making smooth hard roads with a snow roller. (Sci. Am.), April 12, 1919, p. 377, incl. 2 half-tones.

SOUND DETECTOR. See SUBMARINE DEFENSE.

STADIA SURVEYING.

Field methods on rapid stadia surveys at Columbus. H. K. Kistler. (Eng. N.). April 17, 1919, p. 777, incl. charts, sections, etc.

All lines run by stadia, levels taken with transit. Special rod extension. Colored cloths and whistles for signals.

STEAM POWER-PLANTS.

United States nitrate plant, No. 2 at Muscle Shoals, Ala. Condenser equipment. Chas. H. Bromley. (Power), April 15, 1919, p. 558-561, incl. half-tones, plan, sections.

The 60,000-kw. unit has four condensers, each of 25,000 squ. ft. of Muntz metal tube surface. The circulating-water pumping capacity is 132,000 gallons per minute, 44,000 gallons per minute spare.

A forebay with stop-log gallery constitutes the circulating-water inlet. The condensers, with 30 ft., 5½ in. long exhaust connections, are hung from the turbine foundation with no supports under the condensers.

STEAM TURBINES.

The large steam turbine. J. F. Johnson. (Mech. Eng., N. Y.), April, 1919, p. 355-361, incl. half-tones, diagr., sections.

Development of large units to meet modern power requirements. Records of performance. Notes on design and construction.

STEEL.

The hardening of steel. Prof. H. C. H. Carpenter. (Eng.), March 14, 1919, p. 340-341, in 1 diagrs.

SUBAQUEOUS CONCRETE.

Depositing concrete under water. (Eng. W.), April 1, 1919, p. 37-38.

Opinions of the Masonry committee of the Am. Railway Engineering Association respecting the best practices for depositing concrete under water.

SUBMARINE DEFENSE.

Hunting submarines with a sound detector. Brewster S. Beach. (Sci. Am.), April 5, 1919, p. 335, incl. 2 half-tones, 1 chart.

American invention that played an important rôle in the war against the U-Boat.

SUBMARINES.

British submarine building during the war. (Eng.), Feb. 28, 1919, p. 264-266. Fold, plates xiv to xvii.

The ''K'' class of submarines. (Engi.), Feb. 21, 1919, p. 173-174, incl. half-tones, p. 178.

U Boat secrets revealed. (Naut. G.), April 19, 1919, p. 262.

German naval commander discusses submarine operations.

SUEZ CANAL. See also under **FERRIES.**

SURVEYING. See also **STADIA SURVEYING.**

TAPS AND TAPPING. See **MACHINE TOOLS.**

TELEGRAPHY, WIRELESS.

Signaling and talking through space. (Sci. Am.), April 12, 1919, p. 370-371, incl. front., 7 half-tones.

A broad introduction to the present status of wireless telegraphy and telephony.

TELEPHONY, WIRELESS.

Radio telephony. i. E. B. Craft and E. H. Colpitts. (Sci. Am. S.), April 19, 1919, p. 244-246, incl. half-tones, diagrs.

The beginings of long-distance wireless transmission of speech. ii. April 26, 1919, p. 268-271, incl. diagrs., sections.

Naval and airplane installations developed during the war.

TEMPLETS. See **JIGS.**

TOOTHED GEARING. See **GEARING, TOOTHED.**

VENTURI METER. See **HYDRAULICS.**

WATER-SUPPLY. See also **FILTERS AND FILTRATION.**

WATER TERMINALS. See also **ARMY WAREHOUSES.**

The Richborough transporttion depot and train ferry terminus. vi. (Engi.), Feb. 21, 1919, p. 169-172, incl. half-tones, sections, etc.; March 7, 1919, p. 219-220, incl. half-tones, plate xxvi.

WELDING. See also **ENGINEERING—SOCIETIES.**

Electric and oxy-acetylene welding compared. (Naut. G.), April 12, 1919, p. 249.

Mask and body protector for welders. (Eng.), Feb. 21, 1919, p. 252. 250 words. 2 half-tones.

Modern welding and cutting. Ethan Viall. (Am. Mach.). April 10, 1919, p. 675-679, incl. 3 half-tones.

viii. History and uses of the gas torch.

. . .''The present series dealing with gas torch work, is planned to cover the subject more comprehensively from the standpoint of the actual user, than anything that ever has been published''.

The same. ix. Oxygen and hydrogen by the electrolytic method. (Am. Mach.), April 17, 1919, p. 733-737, incl. half-tones, sections, etc.

Notes sur le soudage des verres. Léon Appert. (S. E. I. N.). Jan.-fév., 1919, p. 67-91.

Contents. Avant-propos. Historique. Technique. Soudage des verres entre eux. 1re Condition: Coefficients de dilatation. Observations. Deuxième condition: Athermanisme et diathermanisme. 3me condition: Inaltérabilité et neutralité. Procédés de soudage des verres entre eux. Soudage du verre avec les métaux. Résumé.

WIRE MANUFACTURE.

The manufacture of rafwires and their fittings. (Engi.), Feb. 21, 1919, p. 167-169, incl. 1 half-tone, sections, etc.

WIRELESS TELEGRAPHY. See **TELEGRAPHY, WIRELESS.**

Articles of Engineering Interest.

Compiled with a view to including articles of civil and military engineering subjects of special interest to the readers of Professional Memoirs, Corps of Engineers and Engineer Department at Large. By Henry E. Haferkorn, Librarian, Engineer School.

Note.—The following Abbreviations have been used:

Am. Mach.—American Machinist, New York.

Am. Soc. T.—American Society for Testing Materials, Philadelphia, Pa. Reports, Proceedings.

Am. Soc. C. E. T.—American Society of Civil Engineers, New York. Transactions.

Autom. Ind.—Automotive Industries. The Automobile, New York.

Boston Soc. C. E.—Boston Society of Civil Engineers, Boston, Mass.

Bull. T. S. R.—Bulletin de la Suisse Romande, Lausanne.

Concrete.—Concrete, Detroit, Mich.

Eng.—Engineering, London.

Engi.—The Engineer, London.

Eng. C.—Engineering and Contracting, Chicago, Ill.

Eng. N.—Engineering News-Record, New York.

Eng. R.—The Engineering Record, New York. Merged with Engineering News.

Mech. Eng., N. Y.—Mechanical Engineering. The Journal of the Am. Society of Mechanical Engineers.

Munic. Eng.—Municipal and County Engineering, Indianapolis, Ind.

La Nature.—La Nature, Paris.

Power.—Power, N. Y.

Prof. M.—Professional Memoirs, Washington Barracks, D. C.

Sci. Am.—Scientific American, New York.

Sci. Am. S.—Scientific American Supplement, New York.

AERIAL PHOTOGRAPHY.

Methods used in aëro-photographic mapping. F. H. Moffit. (Eng. N.), v. 82, no. 2. May 22, 1919, p. 1000–1004, incl. 8 figs. (half-tones, diagrs.)

Present status of photographic mapping from air. J. B. Merie, jr. (Eng. N.), v. 82, no. 21. May 22, 1919, p. 996–999.

AMMUNITION DUMPS. See **AMMUNITION—FIELD STORAGE.**

AMMUNITION—FIELD STORAGE.

Ammunition dumps (Prof. M.), Jan.-Feb., 1919, p. 134–136. 2 diagrs.

ARCHES. See **BRIDGES.** See also **STRESSES AND STRAINS.**

(Prepared for Professional Memoirs, v. 11, No. 60, Nov.-Dec., 1919.)

ARMY WAREHOUSES.

New Orleans army base improves facilities of the port. Geo. H. Davies. (Eng. N.), April 24, 1916, p. 823–826, incl. plan, sections.

BRIDGES—FOUNDATIONS AND PIERS.

Obstruction of bridge piers to the flow of water. Floyd A. Nagler. (Am. Soc. C. E. T.), v. lxxxii. Dec., 1918. Paper 1409, p. [334]–395, incl. 22 figs. (half-tones, sections, diagrs., etc.)

Discussion by A. J. Wiley, R. D. Goodrich, E. W. Lane, M. Merriman, F. H. Frankland, C. E. Fowler, R. E. Horton, D. A. Molitor, F. A. Nagler.

BRITISH LIGHT RAILWAYS IN FRANCE. See MILITARY BRIDGES.

BUNKER HILL DIKE. See WATER STORAGE.

CAMOUFLAGE.

Memorandum on the camouflage service of the United States Army. Maj. Evarts Tracy. (Prof. M.), March-April, 1919, p. 175–184, incl. 1 table.

CANALS. See also ICE ON RIVERS, LAKES, ETC.

Projet de canal maritime entre la Mer du Nord et la Mer d'Irlande. Chas. Rabor. (La Nature), v. 45, ptie. ii, no. 2303. 17 nov. 1917, p. 320, incl. 2 plans. LC (Q2N2, v. 45–2)

Illustrations: Fig. 1. Les grandes routes de navigation vers Edinbourg. 2. Le canal projeté à travers l'Ecosse.

CANALS—U. S.

The Cape Cod canal. Wm. Barclay Parsons. (Am. Soc. C. E. T.), v. lxxxii. Dec., 1918. Paper 1403, p. 1–157, incl. discussion by C. Herschel, T. K. Thomson, W. B. Parsons. 41 figs. (Map, profile, sections, diagrs., etc.) Fold. plate no. 1 (Diagrs.).

CAPE COD CANAL. See CANALS—U. S.

CEMENT-CONCRETE.

Final report of the Special committee on concrete and reinforced concrete. (Am. Soc. C. E. T.), v. lxxxi. Dec., 1917. Paper 1398, p. [1101]–1206, incl. 19 figs. (half-tones, diagrs., sections), 4 tables.

CEMENT—TESTING.

Specifications and methods of tests for Portland cement. (Am. Soc. C. E. T.), v. lxxxii. Dec., 1918. Paper 1405, p. [166]–184, incl. 7 figs. (diagrs., etc.)

COBLENZ PONTON BRIDGE. See MILITARY BRIDGES.

COFFER-DAMS.

Nomographic chart in cofferdam design. Letter to editor. Capt. W. A. Lyon, Corps of Engineers. (Eng. N.), May 22, 1919, p. 1029–1030, incl. chart and diagrs.

CONCRETE. See CEMENT—CONCRETE.

CONVEYORS.

The portable scoop conveyor. (Sci. Am. S.) April 26, 1919, p. 264–265, incl. front., half-tones, plan and sections.

The present last word in the transfer of bulk material.

CORROSION AND ANTI-CORROSIVES. See also HOUSE DRAINAGE—PIPES.

CURRENT DEFLECTORS. See ICE ON RIVERS, LAKES, ETC.

CURRENTS, SOUTHWWEST PASS. See MISSISSIPPI RIVER.

DAMS. See also ELEPHANT BUTTE DAM.

DETENTION RESERVOIRS. See FLOOD DAMS AND RESERVOIRS.

DIPPER DREDGES. See DREDGING MACHINERY.

DRAINAGE.

Inspection of drainage ditch cross-sections after contract dredging. E. S. Blaine. (Eng. N.), May 22, 1919, p. 1019–1022, incl. 7 figs. (half-tones, diagrs.).

The subsidence of muck and peat soils in Southern Louisiana and Florida. Chas. W. Okey. (Am. Soc. C. E. T.), v. lxxxii, Dec., 1918, paper 1410, p. [396]–432, incl. 21 figs. (maps, charts, sections, etc., fold. plate v. (map), 2 tables).

DREDGES AND DREDGING. See DREDGING MACHINERY.

DREDGING MACHINERY.

The three 15-cubic yard dipper-dredges, Gamboa, Paraiso, and Cascadas, as supplied and used on the Panama Canal. Ray W. Berdeau. (Am. Soc. C. E. T.), v. lxxxii. Dec., 1918. Paper 1412, p. [515]–550, incl. section, fold. plates vi, vii, 3 tables.

Discussion by Chas. E. Fowler, A. W. Manton, A. W. Robinson, Wm. M. Rosewater.

. . . "Result of the writer's study of the design, operation, and efficiency of the large 15-cu. yd. dipper-dredges supplied by the Bucyrus Company for the Panama canal."—From synopsis.

ELECTRIC WELDING.

Electric arc welding. F. A. Anderson. (Mech. Eng., N. Y.), May, 1919, p. 452–454, incl. half-tones, sections.

Abstract of paper read at meeting of the San Francisco section of the Am. Society of Mechanical Engineers, Feb. 13, 1919.

Electric welding. (Engi.), March 21, 1919, p. 267–268, incl. sections, table.

vi. The quasi arc process.

Electric welding as applied to ship construction. H. J. Cox. (Mech. Eng., N. Y.), May, 1919, p. 439–444, incl. half-tones, sections, etc.

Abstract of paper presented at meeting of the Society of Naval Architects and Marine Engineers, Nov. 14-15, 1918.

Electric welding and welding appliances. vii. (Engi.), March 28, 1919, p. 296–299, incl. half-tones.

vii. Resistance welders of the British Insulated and Helsby Company.

ELEPHANT BUTTE DAM.

Construction features of the Elephant Butte dam. U. S. Reclamation service. (Eng. N.), v. 69. Jan. 16, 1913, p. 120–122, incl. plan.

Elephant Butte dam. (Eng. R.), v. 67, May 17, 1913, p. 557–558, incl. map.

Concrete mixing plant for Elephant Butte dam. L. J. Charles. (Eng. N.), v. 72. Aug. 6, 1914, p. 292–297, incl. illus., plans, diagrs.

Greatest irrigation enterprise in America. (Sci. Am.), v. 111, Aug. 1, 1914, p. 73–74, incl. illus.

Closure made at Elephant Butte dam, New Mexico. (Eng. R.), v. 71, Feb. 27, 1914, p. 274.

Concreting methods and records, Elephant Butte dam. E. H. Baldwin. (Eng. N.), v. 74. Oct. 7, 1915, p. 696–698, incl. diagrs.

Excavation for foundation of Elephant Butte dam. E. H. Baldwin. (Eng. N.), v. 73. Jan. 14, 1915, p. 49–54, incl. illus., plan, diagrs.

Placing masonry for the Elephant Butte dam, New Mexico. E. H. Baldwin. (Eng. N.), v. 74. Sept. 30, 1915, p. 645–649, incl. illus., diagrs.

Comparison of the Elephant Butte and Arrowrock dams. J. F. Slater. (Concrete), v. 11. Dec., 1917, p. 183.

Grouting the foundation of the Elephant Butte dam. E. H. Baldwin. (Eng. N.), v. 78. June 28, 1917, p. 625–628, incl. illus., plan, diagrs.

Slide gates and needle valves in the Elephant Butte dam. F. Teichman. (Eng. N.), v. 77. Feb. 22, 1917, p. 306–308, incl. diagrs.

Back of dam coated by cement gun from raft as pool rises. (Eng. R.), v. 73. March 18, 1916, p. 400.

Costs of applying mortar with the cement gun. (Eng. N.), v. 75. Mar. 9, 1916, p. 469.

Elephant Butte dam. (Engi.), v. 122. Sept. 1, 1916, p. 185–186, 190, incl. illus., plan, sections.

Greatest irrigation storage enterprise in the world. (Sci. Am. S.), v. 82. July 15, 1916, p. 37, incl. illus.

Outlet control of Elephant Butte dam. F. Teichman. (Eng. N.), v. 76. Nov. 30, 1916, p. 1015–1017, incl. plan, diagrs.

ENGINEERING—INSTRUMENTS. See **SCIENTIFIC APPARATUS AND INSTRUMENTS.**

ENGINEERING—RESEARCH. See also **INDUSTRIAL RESEARCH—SCIENTIFIC RESEARCH—LABORATORIES.**

Abstracts of recent papers on Engineering research. (Engineering and Contracting, Chicago), v. 49, no. 9. Feb. 27, 1918, p. 217–221.

Equipping a shop laboratory. (Machinery, N. Y.), v. 24. Aug., 1918, p. 1087–1090.

Coöperation in industrial research. (Iron Age, N. Y.), v. 102, no. 3. July 18, 1918, p. 140–144.

Glazebrook, Sir Richard T.

The National laboratory for industrial research. (Engineering and Contracting, Chic.), v. 50, no. 18. Oct. 30, 1918, p. 423–425.

Hill, Chas. W.

Efficiency in industrial research. (Chemical and Metallurgical Engineering, N. Y.), v. 18. Feb. 15, 1918, p. 182–184.

Hosmer, H. R.

Research laboratory of the General Electric Company at Schenectady. (Sibley Journal, Ithaca, N. Y.), v. 32. April, 1918, p. 93–103.

Hyde, Edw. P.

Aims, organization and work of the Nela research laboratory. (Sibley Journal, Ithaca, N. Y.), v. 32. May, 1918, p. 123–126.

Importance of industrial and trade research brought out by the war. (Engineering News-Record, N. Y. Construction News), v. 81, no. 13. Sept. 26, 1918, p. 159.

Study and use of statistics emphasized by country's vital needs in present situation.

Little, Arthur D.

Organization of industrial research. (Engineering and Contracting, Chicago), v. 50, no. 4. July 24, 1918, p. 90–92.

McDowell, Chas. H.
American research methods. (Western society of Engineers, Chicago. Journal), v. xxii, no. 8. Oct., 1918, p. 546–565, including discussion.

Newman, C.
Research and manufacturing methods. (Machinery, N. Y.), v. 24, June, 1918, p. 908–909.

Nutting, P. G.
Research and the industries. (Sibley Journal, Ithaca, N. Y.), v. 32, March, 1918, p. 81–84.
Organizing research work on a national scale. (Am. Machinist, N. Y.), v. 49, no. 2. July 11, 1918.

Planning a research laboratory for an industry. C. E. K. Mees. (Journal of Industrial and Engineering Chemistry, Easton, Pa.), v. 10. June, 1918, p. 476–480.

Research laboratories should coöperate. (Iron Trade Review, Cleveland, O.), v. 63. July 4, 1918, p. 36–37.

Reese, Chas. L.
Development in industrial research. (Chem. and Metall. Eng., N. Y.), v 19, Aug. 15, 1918, p. 197–199, incl. plan.

Reports upon research. (Mech. Eng., N. Y.) April, 1919, p. 410–413, incl. sections, etc., tables.

The thermal testing plant of the Engineering experiment station. The Pennsylvania State College. (Mech. Eng., N. Y.), May, 1919, p. 464. 1300 words. With bibliographical notes.

Richtmyer, F. K.
Industrial research laboratories. (Sibley Journal, Ithaca, N. Y.), v. 32, March, 1918, p. 80–81.

Skinner, C. E.
The opportunity for industrial research. (Am. Society of Mechanical Engineers, N. Y.), v. 40, no. 1. Jan., 1918, p. 23–24.
Author is Research Engineer, Westinghouse Electric and Manufacturing Co. Article is a brief plea for research work in colleges and plants.

Skinner, C. E., and R. W. E. Moore.
The new Westinghouse Research building. (Electrical World, N. Y.), v. 72, no. 22. June 1, 1918, p. 1132–1133, incl. 6 half-tones.

Testing laboratory at the Fiat Works. (The Engineer, London), v. 125, no. 3261. June 28, 1918, p. 555–556; 558, incl. 6 half-tones.

Why structural and other engineers should take greater interest in scientific research. Editorial. (Engineering and Contracting, Chicago), v. 49, no. 9. Feb. 27, 1918, p. 207–208.

ENGINEERING—SOCIETIES.

The activities of the American Society of Civil Engineers during the past twenty-five years. Chas. W. Hunt. (Amer. Soc. C. E. T.), v. lxxxii. Dec., 1918. Paper 1425, p. [1577]–1652, incl. half-tones, plans.

Reorganization of the Engineering Standards Committee. Edw. B. Rosa. (Eng. N.), May 1, 1919, p. 861–862.

ENGINEERING—STUDY AND TEACHING.

Short courses for engineering graduates. J. O. Kammerman. (Power), May 13, 1919, p. 731–732.

ENGINEER TROOPS—ITALY—ARMY. See **EUROPEAN WAR, 1914-18.**

ENGINEER TROOPS—U. S. ARMY.

Employment of divisional engineers. Headquarters eighth Army Corps, American Expeditionary force, A. P. O. 931. Memorandum. (Prof. M.), March-April, 1919, p. 245–248.

ERICHSEN'S APPARATUS. See **HARDNESS, TESTING OF.**

EUROPEAN WAR, 1914-18. ENGINEER SERVICE. See also **CAMOUFLAGE—ENGINEER TROOPS—MILITARY BRIDGES—MILITARY TOPOGRAPHY—SEARCHLIGHTS.**

Technical engineering details of the Hindenburg line in the sector of attack of the ii. Army Corps. Col. G. B. Pillsbury. (Prof. M.), March-April, 1919, p. 150–174, incl. plans, sections, diag.

EUROPEAN WAR, 1914-18. ENGINEER SERVICE—ITALY.

Notes on the operations of the Italian engineers. Lieut. James H. England. (Prof. M.), Jan.-Feb., 1919, p. 128–133, incl. 5 half-tones.

FLOODS AND FLOOD CONTROL. See also under **WATER STORAGE.**

Miami conservancy construction work not damaged in flood. (Eng. N.), May 1, 1919, p. 860.

FLOOD DAMS AND RESERVOIRS.

Detention reservoirs with spillway outlets as an agency in flood control. H. M. Chittenden. (Am. Soc. C. E. T.), v. lxxxii, Dec., 1918. Paper 1423, p. [1473]–1540, incl. 13 figs. (diag.), 14 tables. Fold plate xlviii.

Discussion by A. E. Morgan, A. R. McKim, T. K. Thomson, A. F. Meyer, W. M. Hall, F. H. Tibbetts, H. A. Petterson, I. E. Houk, K. C. Grant, Morris Knowles.

FORTIFICATION, PERMANENT.

The future of permanent fortifications. Tr. from the French by Capt. C. Beard, Engineers, U. S. A. (Prof. M.), Jan.-Feb., 1919, p. 47–64.

Old and new opinions about the value of permanent and fortified positions. Tr. by Maj. Henry Swift, Chaplain, U. S. A., ret. (Prof. M.), Jan.-Feb., 1919, p. 29–46. Continued from Nov.-Dec., 1918.

FOSTER, JOHN GRAY. See **BIOGRAPHY.**

FUEL. See also **PEAT.**

GAGES.

The measurements of gauges. E. A. Forward. i. (Engi.), March 21, 1919, p. 282–283, incl. 11 figs.; ii. March 28, 1919, p. 294–295, incl. 12 figs.

On some principles of manufacturing interchangeable articles to limit gauges. Prof. G. Gerald Stoney and Mr. S. Lees. (Eng.), March 21, 1919, p. 361–362.

GROUND WATER. See **WATER, UNDERGROUND.**

GUILLERY INSTRUMENT. See **HARDNESS, TESTING OF.**

HARBORS—FRANCE.

Agrandissements du port de Rouen. A. Breton. (La Nature), v. 45, ptie. ii, no. 2302. 10 nov., 1917, p. 303–304, incl. 1 plan.

Le projet Brest-transatlantique. Ch. Lallemand. (La Nature), v. 45, ptie. 2, no. 2287. 28 juillet, 1917, p. 62–63, incl., 1 map.

Projet d'agrandissement du port du Havre. A. Breton. (La Nature), v. 45, ptie. ii, o. 2306. 8 déc., 1917, p. 367–368, incl. 1 plan. LC(Q2,N2,v45-2)

HARBORS—RUSSIA. See also **RAILROADS—RUSSIA.**

HAVRE—HARBOR. See **HARBORS—FRANCE.**

HELL GATE ARCH BRIDGE. See also **BRIDGES.**

The Hell Gate Arch Bridge and approaches of the New York connecting railroad over the East River in New York City. O. H. Ammann. (Am. Soc. C. E. T.), v. lxxxii. Dec., 1918. Paper 1417, p. [852]–1039, incl. 66 figs. (1 map, 1 plan, 33 half-tones, 12 tables). Fold. plates xxiv–xliii (map, profile, plans, sections, 7 tables).

Discussion by W. H. Breithaupt, L. S. Moisseiff, S. T. Wagner, C. E. Fowler, H. H. Quimby, H. B. Seaman, G. Lindenthal, C. E. Chase and author.

HYDRAULICS. See also under **BRIDGES—FOUNDATIONS AND PIERS—ICE ON RIVERS, LAKES, ETC.**

ICE DIVERSION. See **ICE ON RIVERS, LAKES, ETC.**

ICE ON RIVERS, LAKES, ETC.

Ice diversion, hydraulic models and hydraulic similarity. B. F. Groat. (Am. Soc. C. E. T.), v. lxxxii. Dec., 1918. Paper 1419, p. [1138]–1190, incl. half-tones, diagrs., tables 1–3.

Discussion by M. O. Leighton, J. W. Smith, R. Fletcher, A. F. Parker, E. E. R. Tratman and author.

INSTRUMENTS—ENGINEERING. See **SCIENTIFIC APPARATUS AND INSTRUMENTS.**

JIGS.

Jigs tools and special machines with their relation to the production of standardized parts. Herbert C. Armitage. (Eng.), March 28, 1919, p. 402–406, incl. sections, etc., tables i-iii.

LABORATORIES.

The relation between the laboratory and the workshop. W. R. Barcley. (Eng.), April 4, 1919, p. 456–457.

Steel research laboratory planned for the Carnegie Institute of Technology. Contributed by Thom. S. Barker. (Mech. Eng., N. Y.), May, 1919, p. 465–466, incl. detail drawing.

LAND DRAINAGE. See **DRAINAGE.**

LANDSLIDES.

A phenomenal land slide—supplement. D. D. Clarke. (Am. Soc. C. E. T.), v. lxxxii, Dec., 1918. Paper 1415, p. [767]–801, incl. 11 half-tones, 3 sections, 2 fold plates (maps, diagr.).

Discussion by G. L. Dillman and D. D. Clarke.

LITTLE RIVER DRAINAGE DISTRICT. See **DRAINAGE.**

LOCKS (CANALS). See **LOCKS AND LOCK GATES.**

LOCKS AND LOCK-GATES.

The distribution of stresses in mitering lock-gates, with special reference to the gates on the Panama Canal. Henry Goldmark. (Am. Soc. C. E. T.), v. lxxxi. Dec., 1917. Paper 1402, p. [1621]–1655, incl. half-tones, diagrs., 7 tables. Fold. plates xvi, xvii.

MACHINE-SHOP PRACTICE.
Machine tools and workshop methods of a former period. Sir Alfred Herbert. (Engi.), March 21, 1919, p. 283–284.

MACHINE TOOLS. See also **JIGS.**

MANHATTAN ELEVATED RAILWAY. See **RAILROADS, ELEVATED.**

MECHANICAL UTENSILS. See also **JIGS.**

METALS—TESTING. See also **HARDNESS, TESTING OF.**

METALLURGY.
On the metallurgical information required by engineers. Lieut. Col. C. F. Jenkin. (Engi.), April 4, 1919, p. 325–326.

MILITARY BRIDGES.
The Coblenz ponton bridge. Maj. J. W. Skelly. (Prof. M.), March-April, 1919, p. 217–288, incl. half-tones, plans, sections, etc.

MILITARY MAPPING. See also **MILITARY TOPOGRAPHY.**

MILITARY TOPOGRAPHY.
Comment on the military mapping problems in the U. S. Col. E. H. Marks. (Prof. M.), March-April, 1919, p. 241–244.
The military mapping problem in the United States. Lieut. Col. R. C. Kuldell. (Prof. M.), March-April, 1919, p. 229–248, incl. 1 map, 1 chart.

MISSISSIPPI RIVER.
Currents at and near mouth, Southwest Pass, Mississippi River. T. E. L. Lipsey. (Prof. M.), Jan-Feb., 1919, p. 65–122, maps, charts, etc.

MITERING LOCK-GATES. See **LOCKS AND LOCK-GATES.**

MURMANSK SEAPORT. See **HARBORS—RUSSIA.** See also **RAILROADS—RUSSIA.**

OLSEN'S HARDNESS TESTING MACHINE. See also **HARDNESS, TESTING OF,**

PACK TRANSPORTATION.
Use of pack mules for carrying rock. (Prof. M.), Jan.-Feb., 1919, p. 127.

PANAMA CANAL. See also **DREDGING MACHINERY—LOCKS AND LOCK-GATES.**

PARAVANE.
The protection of ships against mines. ii. (Engi.), March 28, 1919, p. 293–294, incl. half-tones, diagrs.

PAVEMENTS.
Contour of pavement traced to exaggerated scale. (Eng. N.), May 22, 1919, p. 1026–1027, incl. sections, etc.
Device measures irregularities of surface and plots profile with the ordinates multiplied by three.

PEAT.
The utilization of peat for power. ii. John B. C. Kershaw. (Engi.), March 21, 1919, p. 265–267, incl. half-tones, plans, sections.
iii. Carbonizing. iv. Gasifying the peat in gas producers. v. Powdered peat as a boiler fuel. Conclusions.

PIPE LINES.

Air tanks on pipe lines. Minton M. Warren. (Am. Soc. C. E. T.), v. lxxxii, Dec., 1918, paper 1407, p. [250]–277, incl. sections, diagrs., 1 table.

Discussions by Irving P. Church, R. D. Johnson, P. Wahlman, L. R. Jorgensen, M. M. Warren.

Pulsations in pipe lines as shown by some recent tests. H. C. Vensano. (Am. Soc. C. E. T.), v. lxxxii, Dec., 1918, paper 1406, p. [185]–249, incl. 33 figs. (half-tones, diagrs., etc.).

Discussions by N. R. Gibson, R. Hering, R. D. Johnson, M. W. Warren, H. C. Vensano.

PIPES, WOOD.

Modern practice in wood stave pipe design and suggestions for standard specifications. J. F. Partridge, jr. (Am. Soc. C. E. T.), v. lxxxii, Dec., 1918, paper 1411, p. [433]–514, incl. 10 figs. (half-tones, sections. etc., tables 1–4.)

Discussion by H. von Schrenk, F. F. Bell, D. C. Henry, H. P. Rust, F. M. Robbins, Wm. J. Boucher, J. C. Ralston, O. P. M. Goss, W. H. R. Nimmo, E. A. Moritz, A. N. Miller.

POWER PLANTS. See also under **ICE ON RIVERS, LAKES, ETC.**

PROJECTILES—MANUFACTURE.

Manufacturing the 9.2-in. Howitzer shell. S. A. Hand. (Am. Mach.). April 24, 1919, p. 799–801, incl. half-tones, sections.

i. Machining operations.

PUBLIC WORKS.

Engineering societies organize to push Public Works Department bill. (Eng. N.), May 1, 1919, p. 855–860.

Reply of the Corps of Engineers, U. S. A. M. O. Leighton. (Highway Eng.), July, 1919, p. 32–33.

RAILROADS, ELEVATED.

Manhattan elevated railway improvements. F. W. Gardiner and S. Johannesson. (Am. Soc. C. E. T.), v. lxxxii, Dec., 1918, paper 1413, p. [551]–752, incl. half-tones, plans, sections, etc., fold. plates viii–xix, 2 tables.

Discussions by C. E. Carpenter, G. H. Pegram, T. K. Thomson, Edw. Wegmann, H. Constable.

RAILROADS, MILITARY.

A technical description of the British light railways in France. Lt. Col. B. W. Guppy. (Prof. M.), March-April, 1919, p. 185–216, incl. tables.

RAILROADS—RUSSIA.

Murman railroad: new outlet to sea in Russia. V. Goriachovsky. (Eng. N.), May 22, 1919, p. 1023–1026, incl. half-tones, map.

RAILROADS—TRACK.

Progress report of the Special committee to report on stresses in railroad tracks. (Am. Soc. C. E. T.), v. lxxxii, Dec., 1918, paper 1420, p. [1191]–1389, incl. 141 figs. (half-tones, sections, diagrs., etc.), 13 tables.

RAIN AND RAINFALL. See also **WATER STORAGE.**

RIVERS. See also **ICE ON RIVERS, LAKES, ETC.**

ROADS.

Final report of the Special committee on materials for road construction and on standards for their test and use. (Am. Soc. C. E. T.), v. lxxxii, Dec., 1918, paper 1421, p. [1384]–1468, incl. tables.

W. W. Crosby, Chairman of committee.

Discussion by E. Dow Gilman and J. O. Preston.

ROUEN—HARBOR. See **HARBORS—FRANCE.**

RUN-OFF. See **RAIN AND RAINFALL.**

SAN BERNARDINO BASIN. See **WATER STORAGE.**

SCIENTIFIC APPARATUS AND INSTRUMENTS. See also **HARDNESS, TESTING OF.**

SCLEROSCOPE. See under **HARDNESS, TESTING OF.**

SCREW THREADS. See also under **ENGINEERING—RESEARCH.**

SEA MINES. See also **PARAVANE.**

SEARCHLIGHTS.

The development of anti-aircraft searchlights. Lieut. Col. J. B. Cress. (Prof. M.), March-April, 1919, p. 139–149, incl. 6 half-tones.

SEWAGE DISPOSAL.

The disposal of sewage by treatment with acid. Edgar S. Dorr and Robt. Spur Weston. (Boston Soc. C. E.), April, 1919, p. 145–175. With discussion. Tables 1–9. With bibliographical and other foot-notes.

Discussion of this paper is invited.

Sewage disposal by dilution, including chlorination of sewage effluent and treatment of sludge. W. C. Easdale. (Eng. C.), April 30, 1919, p. 456–459, incl. plan, section, tables.

SEWERAGE.

Operation of fine sewage screens at Long Beach, California. (Eng. N.), May 22, 1919, p. 1012–1013.

Tests indicate that screens remove 16.3 per cent of solids. Screenings incinerated by gas. Operating costs.

STEEL.

The hardening of steel. Prof. H. C. H. Carpenter. (Eng.), March 28, 1919, p. 386–390, incl. half-tones.

From a discourse delivered at the Royal Institution, March 7, 1919.

STRESSES AND STRAIN.

Stress measurements on the Hell Gate Arch Bridge. D. B. Steinman. (Am. Soc. C. E. T.), v. lxxxii, Dec., 1918, paper 1418, p. [1040]–1137, incl. 17 figs. (diagrs., sections, etc.), 9 tables. Fold. plates xliv–xlvii.

Discussion by H. J. Bingham Powell, J. A. L. Waddell, F. H. Frankland, L. A. Waterbury, F. D. Hughes, A. H. Fuller, J. E. Howard, I. Delson, G. Lindenthal, J. I. Parcel, H. M. MacKay, F. E. Turneaure, H. S. Jacoby, O. H. Ammann, C. A. Randorf, D. A. Molitor, and author.

SOUTHWEST PASS, CURRENTS AT. See **MISSISSIPPI RIVER.**

SUBWAYS.

Construction problems of the Manhattan-Bronx, and Lexington Avenue subway junction and Queensborough tunnel connections. George Perrine. (Am. Soc. C. E. T.), v. lxxxii. Dec., 1918. Paper 1408, p. [278]–333, incl. 33 figs. (half-tones, sections, etc.). Fold. plates ii-iv. Table i.

Discussion by John Hays Myers, C. E. Carpenter, Robt. A. Shailer, Robt. Ridgway, H. H. Quimby, C. V. V. Powers.

TOWBOATS.

Speed and list in side launching of Ohio River boat. (Eng. N.), May 22, 1919, p. 1017, incl. 1 section.

TRANSPORTATION—RUSSIA. See also **RAILROADS—RUSSIA.**

TUNNELS AND TUNNELING. See also **SUBWAYS.**

VENTURI METER. See **WATER METER.**

WATER CODE—ARIZONA. See **WATER—LAWS AND LEGISLATION.**

WATER, FLOW OF, IN OPEN CHANNELS. See **HYDRAULICS.**

WATER METER.

Devices for water-waste surveys at Oak Park, Illinois. (Eng. N.), April 24, 1919, p. 829–831, incl. 2 half-tones, sample charts.

WATER STORAGE.

Hydraulic phenomena and the effect of spreading of flood water in the San Bernardino Basin, Southern California. A. L. Sonderegger. (Am. Soc. C. E. T.), v. lxxxii. Dec., 1918. Paper 1416, p. [802]–851, diagrs., tables 1–4. Fold. plates xxii, (map, diagr.).

Discussion by Chas. H. Lee, J. H. Forbes, and author.

WATER-SUPPLY—NEW ORLEANS.

Unique features of unified operation of water, sewage and drainage facilities at New Orleans, La. Geo. G. Earl. (Munic. Eng.), April, 1919, p. 121–128, incl. 3 half-tones.

WATER TRANSPORTATION.

Les transports par eau et la guerre. Aug. Pawlowski. (La Nature), v. 45, ptie. ii, no. 2291. 25 août, 1917, p. 113–118, incl. map, chart, half-tones.

LC(Q2N2v.45-2)

WATER, UNDERGROUND. See also **WATER STORAGE.**

WELDING.

Modern welding and cutting. Ethan Viall. (Am. Mach.), May 1, 1919, p. 833–838, incl. half-tones, sections.

xy-acetylene welding and cutting. (Power), April 29, 1919, p. 665–6[illegible]

Suggestions in welding cutting tools. C. A. Hart. (Am. Mach.), April 24, 1919, p. 778. 370 words.

WOOD STAVE PIPES. See **PIPES, WOOD.**

PERSONAL NOTES.

Capt. Edward Van Kinkle, 24th Engineers, recently discharged, is now associated with Frederick A. Waldron, consulting engineer, 37 Wall Street, New York City.

Lieut. George A. Grorloff, recently discharged, has become associated with the Towanda Construction Co., as superintending engineer on State highway construction near Towanda, Penn.

Lieut. Col. E. F. Miller, Corps of Engineers, U. S. A., Class 1915, U. S. M. A., has resigned and is associated with his father in the manufacture of farm wagons in Iowa. Colonel Miller was in Europe with the 1st Engineers for over two years.

Col. Clarence S. Coe, of St. Augustine, Fla., who commanded the 17th U. S. Railway Engineers on their return from France, has been appointed by the Jugo-Slav Republic to take charge of railway construction in that country.

COMMANDING OFFICERS OF ENGINEER REGIMENTS.

1st Engineers, Col. James J. Loving, with 1st Division.

2nd Engineers, Col. Glen E. Edgerton, with 2nd Division.

3rd Engineers, Col. Henry C. Newcomer, Philippines, Hawaii, Canal Zone.

4th Engineers, Col. William P. Wooten, with 4th Division.

5th Engineers, Col. Richard Park, Camp Humphreys, Va.

6th Engineers, Col. Clarence L. Sturdevant, with 3rd Division.

7th Engineers, Col. William D. A. Anderson, with 5th Division.

8th Engineers, Col. Robert R. Neyland, Jr., Mounted.

9th Engineers, Maj. Raymond G. Moses, Mounted.

318th Engineers, Col. Jarvis J. Bain, with 6th Division.

PR

Engineering -
F

Vol. XI NOVEMBER-DECEMBER, 1919 No. 60

PROFESSIONAL MEMOIRS

CORPS OF ENGINEERS, UNITED STATES ARMY

AND

ENGINEER DEPARTMENT AT LARGE

Published Bi-monthly at Washington Barracks, D. C.
Under Supervision of Training Section
Office Chief of Engineers, U. S. Army

Entered as Second Class Matter December 26, 1911, at the post-office at Washington, D. C., under the act of March 3, 1879. Copyright, 1919. "Acceptance for mailing at special rate of postage provided for in Sec. 1103, Act of October 3, 1917, authorized June 27, 1918."

Davis-Bournonville Co.

General Offices: Jersey City, N. J.

Factories: Jersey City, N. J.
Elkhart, Indiana
Niagara Falls, Canada

Engineering Sales Offices in Principal Cities

Government Sales Office: 412-413 Colorado Bldg., Washington, D.C.

Manufacturers of

Standard and Special Apparatus for Metal Operations with Oxygen-Hydrogen-Acetylene

Automatically or Hand-Operated

Equipment Developed for Special Conditions

Complete equipment for generating, storing and compressing oxygen, hydrogen and acetylene into stationary or portable containers for shop or field use.

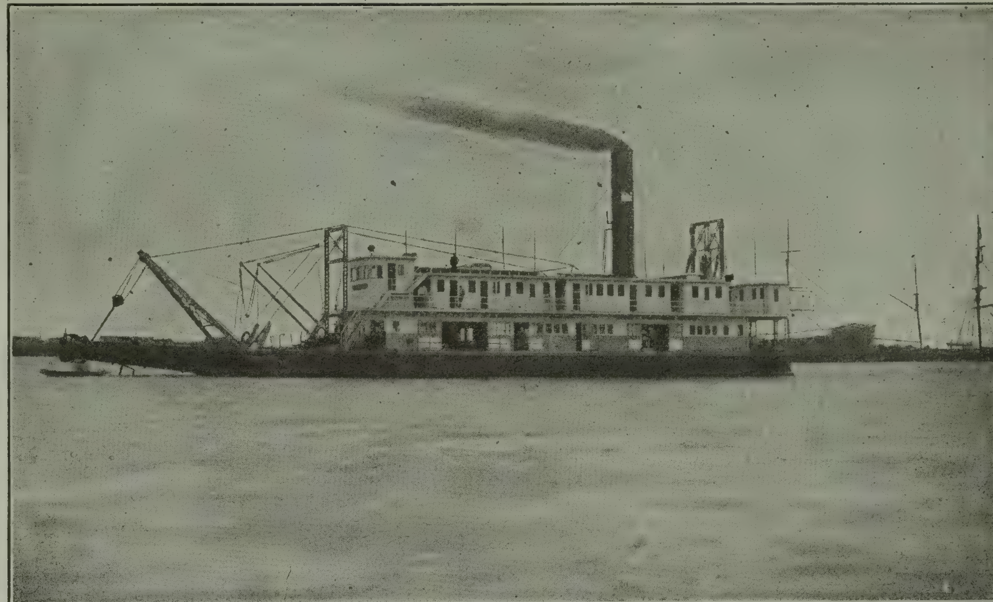
Complete Descriptive Literature on Request.

Correspondence solicited regarding any special or regular service requirement. Facilities of our engineering, sales, and service staff at the disposal of those interested.

Ellicott Machine Corporation

BALTIMORE, MD.

We build Hydraulic Dredges to handle any material (except ledge rock) to any distance, to any height, in any quantity. *Correspondence Solicited.*



Steel Hull Hydraulic Dredge "Gulfport," built by Ellicott Machine Corporation. Baltimore, Md., at work in Gulfport Harbor, Miss.


GREAT LAKES
DREDGE & DOCK COMPANY
ENGINEERS AND CONTRACTORS FOR
RIVER AND HARBOR IMPROVEMENTS
FOUNDATIONS, BRIDGES, PIERS, BREAKWATERS, LIGHTHOUSES, TUNNELS, PNEUMATIC AND SUB-MARINE WORK
WESTERN BRANCHES
CHICAGO, ILL. MONROE BUILDING
MILWAUKEE, WIS. 491-509 CANAL ST.
DULUTH, MINN. ALWORTH BUILDING
SAULT STE MARIE, MICH. ADAMS BUILDING
AMHERSTBURG ONT., CANADA
CLEVELAND, OHIO WILLIAMSON BUILDING
BUFFALO, N. Y. D. S. MORGAN BUILDING
EASTERN BRANCHES
NEW YORK, N. Y. WHITEHALL BUILDING
ALBANY, N. Y. 27 LUMBER DISTRICT
BOSTON, MASS. OLIVER BUILDING
CANAL LOCK, "PANAMA TYPE," BUILT FOR
CORPS OF ENGINEERS, U. S. ARMY
AT "SOO", MICH.

UNIVERSITY OF ILLINOIS-URBANA
3 0112 032405331